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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

THE ADMINISTRATOR

August 8, 1974

Dear Mr. President:
Dear Mr. Speaker:

I am transmitting to the Congress the National Water Quality Inventory Report for 1974, as required by Section 305(a) of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). It is the first in a series of reports to be prepared by EPA in cooperation with the States and other Federal agencies.

The report provides an initial summary of the Nation's water quality, particularly focusing on 22 major waterways selected because of their length, volume, or proximity to major cities. In addition, major point sources of pollution and major problem areas identified by the States and EPA field offices are inventoried in detail.

The results of the inventory and analysis show that:

- Pollution affects or threatens over 3,000 waterway segments of varying lengths and areas in 56 States and territories.
- Chemical and physical measurements taken in the 22 waterways show that the pollutants receiving the most widespread controls – including bacteria and oxygen demand – generally improved in the past 5 years.
- Nitrogen and phosphorus, the nutrients most frequently associated with eutrophication, showed worsening trends. Phosphorus levels were high enough to exceed suggested levels in up to 57 percent of the reaches studied. Although the study did not find widespread eutrophication problems today in the 22 waterways, the worsening trends suggest further study is needed.
- The sources of pollution in U.S. waters are highly varied, but include nationally up to 75,000 industrial, municipal, and agricultural point sources; a variety of nonpoint sources, such as agricultural runoff, urban runoff, and mine drainage; and physical modifications of the waterways themselves, such as dams, dredging, and erosion.

This report is the first systematic inventory of the Nation's water quality. I am confident that we will all benefit by reviewing these data and analyses. We welcome comments from the Congress, the public, and the scientific and technical community. As comments are received, and as additional monitoring and planning data become available, the report can be expanded and improved. With the assistance of the States, we look forward to advancing our knowledge in future years in the reports required by Section 305(b).

Sincerely yours,

Russell E. Train

Russell Train

Honorable Gerald R. Ford
President of the Senate
Washington, D.C. 20510

Honorable Carl B. Albert
Speaker of the House of Representatives
Washington, D.C. 20515

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INTRODUCTION AND SUMMARY

This report was prepared by the U.S. Environmental Protection Agency (EPA), with data and other inputs from States and other Federal agencies. It was prepared pursuant to Section 305(a) of the 1972 Federal Water Pollution Control Act Amendments (Public Law 92-500), which calls for a report which shall:

- "describe the specific quality, during 1973 . . . of all navigable waters and the waters of the contiguous zone,"
- "include an inventory of all point sources of discharge . . . of pollutants" into these waters, and
- "identify specifically those navigable waters, the quality of which is adequate now, or will be adequate [by 1977, 1983, or beyond] to provide for the protection and propagation of . . . shellfish, fish, and wildlife, and allow recreational activities in and on the water."

The report is organized into three parts paralleling those requirements:

Part I: Water Quality Status (Chapters I through X)

Part II: Point Source Inventory (Chapter XI)

Part III: Water Quality Goals (Chapters XII and XIII)

This 1974 report was produced primarily by EPA's Office of Water Planning and Standards, using data collected by EPA, other Federal agencies, and the States, and incorporating problem assessments prepared by the States and reviewed by EPA's Regional Offices. It is the first in a series of reports to be produced each year by the States and EPA, as directed by Section 305(b) of the 1972 Act.

In 1973 EPA and the States started a number of new activities to collect the stream quality and effluent data necessary to implement the 1972 Act, and to report to Congress and the public. Since very few of the 1973 data could be processed in time for this report, EPA supplemented the 1973 data with 1968-72 and earlier data where necessary.

This report marks the first systematic analysis of the quantitative impact of water pollution on a national scale. As such, it is only a beginning. The report focuses on 22 major waterways, approximately 5,000 major point sources, and major problem areas in 56 States and territories. In future years, States will provide more comprehensive data.

SUMMARY

National Segment Inventory

In 1973, the States and EPA cooperated to produce an inventory and provisional classification of 3,313 waterway segments of interest for pollution control. The segments include:

- 1,546 segments that should be able to meet water quality standards using point source controls Congress requires to be available by 1977. These are the so-called *effluent-limited* segments.

- 1,609 segments where more stringent controls might be required to meet standards, or where new sources might threaten to degrade water quality. These are the *water-quality-limited* segments.
- 158 segments not classified.

Based on State assessments, 1,343 of the 1,546 effluent-limited segments should be able to meet standards by 1977. Delays in installing controls may extend the date beyond 1977 for the other 203 effluent-limited segments. The date for clean-up of the 1,609 water-quality-limited segments will generally extend beyond 1977, and in some cases beyond 1983.

Sources of Pollution

Point sources, nonpoint sources, and physical modifications of waterways all cause pollution. Since effluent controls are generally available for point sources now, Congress enacted a discharge permitting system in 1972 to ensure that these controls are installed as soon as possible. EPA expects to receive permit applications from up to 75,000 sources; as of March 1974, about 41,000 applications were being processed and 5,100 had been issued (Table 1).

TABLE 1

U.S. WATERWAYS: POINT SOURCE DISCHARGES

	Industrial/ commercial*	Municipal*	Agricultural*
Applications expected	32,000	31,000-36,000+	6,500
Applications received for processing	24,500	15,600	1,200
Permits issued	3,900	1,200	—

*Federal facilities are included in these categories.
+Includes 10,000 to 15,000 privately-owned treatment works.

22 Major Waterways

As a first step toward "describing the specific quality . . . of all navigable waters,"* EPA selected the 22 largest and most populated waterways of the United States for intensive study. These are:

- The 10 longest rivers in the country: the Missouri, Mississippi, Rio Grande, Yukon, Arkansas, Colorado, Columbia-Snake, Ohio, Red, and Brazos Rivers.
- The 10 rivers with the highest volume of streamflow: the Tennessee, Alabama-Coosa, Susquehanna, and Willamette Rivers (in addition to the Mississippi, Ohio, Columbia, Missouri, Red, and Arkansas listed above).
- The rivers or harbors on which the 10 largest urban areas are located: Hudson River-New York Harbor; Los Angeles Harbor; Lake Michigan shore and other waters of the Chicago area; Delaware River (Philadelphia); Detroit River (Detroit); Sacramento River and San Francisco Bay; Potomac River (Washington, D.C.); and Boston Harbor; as well as the Ohio River (Pittsburgh) and Mississippi and Missouri Rivers (St. Louis) listed above.

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*As required by 305(a)(1) of Public Law 92-500, which reads in full: "Sec. 305. (a) The Administrator, in cooperation with the States and with the assistance of appropriate Federal agencies, shall prepare a report to be submitted to the Congress on or before January 1, 1974, which shall– (1) describe the specific quality, during 1973, with appropriate supplemental descriptions as shall be required to take into account seasonal, tidal, and other variations, of all navigable waters and the waters of the contiguous zone. . ."

The study utilized chemical and physical data collected in over 1.2 million data values during the 1963-72 period at 1,300 locations, and stored in EPA's computerized data system, STORET.

The study shows that the pollutants that have received the most widespread controls, including oxygen-demanding loads and bacteria, are improving. On the other hand, nitrogen and phosphorus, the nutrients most often associated with eutrophication, showed worsening trends.

- The pollutants receiving the most widespread controls–coliform bacteria and oxygen-demanding organic materials–show general improvements in the past 5 years. Dissolved oxygen and oxygen-demand levels improved in up to 74 percent of the reaches, and coliform bacteria improved in up to 78 percent of the reaches.

- For nutrients, up to 57 percent of the reaches exceed EPA's guidelines for phosphorus (100 micrograms per liter) set to protect against accelerated eutrophication in flowing streams. Furthermore, 82 percent of the reaches show increased phosphorus levels in 1968-72 over the previous 5 years. The nitrogen nutrients exceed reference levels in one-quarter of the reaches measured, and increased in up to 76 percent of the reaches.

- Other pollutants with high levels are phenols (industrial compounds that can affect fish flesh palatability and produce taste and odor in drinking water) and suspended solids (which interfere with some aquatic life processes). In reaches with data, phenols and suspended solids generally improved in the past 5 years.

- Data on heavy metals and pesticides were too limited to determine trends, but did indicate that, for 50 percent of the reaches over the past five years, cadmium, lead, mercury, iron, manganese, 2, 4-D, and 2,4,5-T each exceeded drinking water supplies reference levels on at least one occasion.

Seven of the 22 rivers are reported in greater detail than the others because they had the most data readily available. They are the Mississippi River (Chapter III), Missouri River (Chapter IV), Ohio River (Chapter V), Tennessee River (Chapter VI), Detroit River (Chapter VII), Columbia-Snake Rivers (Chapters VIII and IX), and Willamette River (Chapter X). Results are summarized in Table 2.

TABLE 2

CONDITIONS OF EIGHT RIVERS STUDIED

River	Harmful substances	Physical modification	Eutrophication potential
Mississippi (Chapter III)		High* turbidity and solids below Missouri R.	High* increasing nutrients but no algae
Missouri (Chapter IV)	Trace metals present in middle river	High* suspended solids, turbidity in middle, lower river	High*, increasing nutrients but no algae
Ohio (Chapter V)	High*, increasing iron and manganese	High* suspended solids in lower river some improvements	High* nutrients but no algae
Tennessee (Chapter VI)			Small increase in nutrients but no algae
Detroit area (Chapter VII	Cyanides present but improving	Suspended solids improving; local temperature effects from discharges	Nutrients discharged to Lake Erie decreasing
Columbia (Chapter VIII)	Severe gas super saturation; some radioactivity, lower river	Occasional high* temperatures	High* nutrients but no algae, except for slime growths in lower river
Snake (Chapter IX)	Severe gas super saturation; significant pesticides	Turbidity from natural erosion, agricultural practices, reservoir flushing	Nuisance algae blooms each summer
Willamette (Chapter X)	Significant sulfite waste liquor from pulp, paper wastes	High* turbidity at high flow; high temperature in summer	High* level of nutrients but no excessive algae

TABLE 2 (Continued)

CONDITIONS OF EIGHT RIVERS STUDIED

River	Salinity, acidity, and alkalinity	Oxygen depletion	Health hazards and aesthetic degradation
Mississippi (Chapter III)	High* salinity, acidity below major tributaries	Oxygen-demanding loads from large cities evident	Commercial fishing eliminated in lower river by phenols; bacteria near cities
Missouri (Chapter IV)	High* dissolved salts in middle, lower river	High* organic loads from feedlots, etc.; improved near cities	High* bacteria and viruses present in wet, dry periods
Ohio (Chapter V)	Low* alkalinity especially in upper river	Occasional low* dissolved oxygen near Cincinnati, Pittsburgh	High* bacteria especially in high population areas
Tennessee (Chapter VI)		Low* BOD, and decreasing COD in reservoirs	High* bacteria in small areas near cities; low radionuclides
Detroit area (Chapter VII)	Acids, chlorides low,* improving despite large discharges	Low* dissolved oxygen only at mouths of area tributaries	Phenols decreasing; bacteria unchanged-to-higher
Columbia	Approaches ideal for fresh waters	Dissolved oxygen close to saturation	Very low* bacteria
Snake (Chapter IX)	High* dissolved solids from irrigation in middle river	Dissolved oxygen close to saturation	High* bacteria below population centers
Willamette (Chapter X)	Low* dissolved mineral salts; improved pH	Improved dissolved oxygen; no standards violations	High* bacteria, but improving

*High (or low) relative to other rivers, or relative to other sections of river, or to national reference levels. Does not necessarily imply standards violations or dangerous condition.

PART I
WATER QUALITY STATUS

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I. STUDY METHOD

This part of the report (Chapters I through X) focuses on the Nation's largest rivers and the waters near our largest cities. The report's objective is to find out how clean or dirty these waters are, and to describe pollution where it exists. The results illustrate the scope and diversity of water quality problems found throughout the United States in larger rivers and populated areas.

WATERWAYS EXAMINED

A river or waterway was selected for inclusion in this part of the report if:

- It is among the 10 longest rivers in the continental United States and Alaska.
- It is among the 10 rivers with the highest annual volume of water flow.
- It is located near one of the 10 largest urban areas in the United States, as defined by the Census Bureau's Standard Metropolitan Statistical Areas (SMSA's).

A total of 17 rivers and 5 other waterway areas meet these criteria (Table I-1 and Figure I-1). Together, these 22 major waterways represent about 20,000 miles of the estimated 3.5 million miles of rivers and streams in the United States. They are important nationally because:

- They receive the water that drains from about 70 percent of the Nation's 3.6 million square miles (Figure I-2).
- Approximately 125 million people inhabit their drainage areas, including 70 million people in 77 large populated areas on or along the 22 major waterways (Table I-2 and Figure I-3).
- Of the 22 waterways, 15 supply drinking water systems of 84 large communities (that is, 25,000 people or more) serving 29 million people.
- The 17 rivers contain 63 of the largest reservoirs in the Nation, totaling 54 percent of the man-made storage capacity in reservoirs of 5,000 acre-feet or more. The 12 reservoirs on the upper Missouri and the four on the Colorado alone account for 39 percent of the total U.S. storage capacity (Table I-3).
- The waterways represent a wide variety of flow and climatic conditions: in terms of water volume, the largest river, the Mississippi, has 220 times the average annual flow of the smallest, the Brazos (Table I-4). Conditions on a waterway can vary tremendously depending on flow: a river on a day of maximum flow often carries over 1,000 times as much water as on a day of minimum flow.

DATA SOURCES AND ANALYSIS

EPA's storage and retrieval (STORET) computerized data base was used for the analysis. This data base contains data from over 60,000 surface water quality monitoring stations for some 1,500 water quality parameters, usually referred to as parameters. This large volume of data comes from over 190 offices representing 68 Federal, State, interstate, and local agencies.

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Figure I-1

22 MAJOR WATERWAYS STUDIED BY EPA

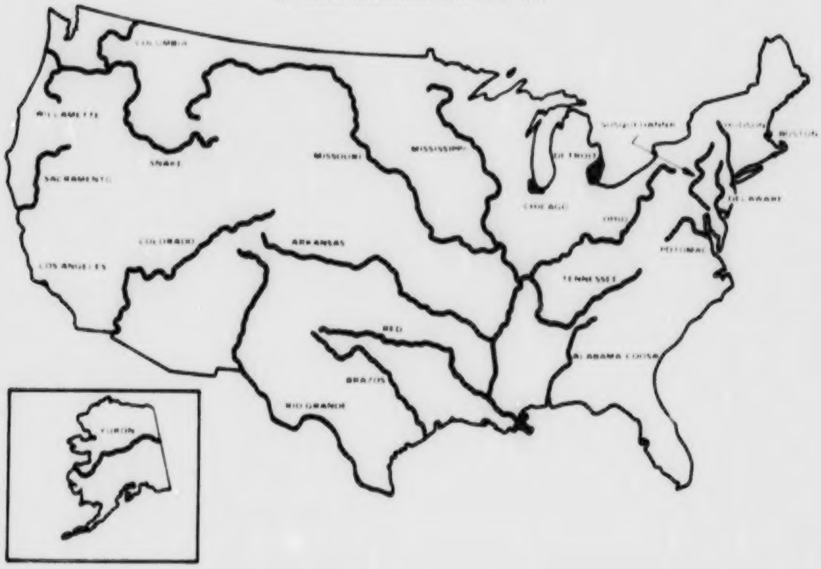
COLUMBIA
WILLAMETTE
SNAKE
SACRAMENTO
MISSOURI
MISSISSIPPI
SUSQUEHANNA
HUDSON
BOSTON
DETROIT
CHICAGO
DELAWARE
OHIO
POTOMAC
COLORADO
ARKANSAS
LOS ANGELES
TENNESSEE
RED
ALABAMA COOSA
BRAZOS
RIO GRANDE
YUKON

TABLE I-1

MAJOR U. S. WATERWAYS

10 Longest rivers (miles)*	10 Rivers with highest flows + (cubic feet per second)	Waters of 10 largest urban areas
Missouri (2,564)	Mississippi (620,000) ‡ **	Hudson River – New York Harbor
Mississippi (2,348)	Ohio (255,000) ‡	Los Angeles Harbor
Rio Grande (1,885)	Columbia (235,000) ‡	Lake Michigan and other waters of Chicago area
Yukon (1,875)	Missouri (70,100) ‡	Delaware River (Philadelphia)
Arkansas (1,450)	Tennessee (63,700)	Detroit River and Detroit area tributaries
Colorado (1,450)	Alabama-Coosa (59,000)	San Francisco Bay and Sacramento River
Columbia-Snake (1,324)	Red (57,300) ‡ ++	Potomac River (Washington, D.C.)
Ohio (1,306)	Arkansas (45,200) ‡	Boston Harbor
Red (1,222)	Susquehanna (35,800)	Ohio River (Pittsburgh) ‡
Brazos (1,210)	Willamette (30,700)	Mississippi and Missouri Rivers (St. Louis) ‡

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*Source: U.S. Army Corps of Engineers. Published in *The Water Encyclopedia*, Water Information Center, Port Washington, N.Y. 1970, p. 118.

+Source: U.S. Geological Survey, 1921-45 data; excludes Great Lakes connecting waters and St. Lawrence River.

‡Contained in first (or second) columns.

**Includes Atchafalaya River (about 25 percent of flow).

++Includes flow of Ouachita River

Figure I-2

AREA DRAINED BY MAJOR WATERWAYS

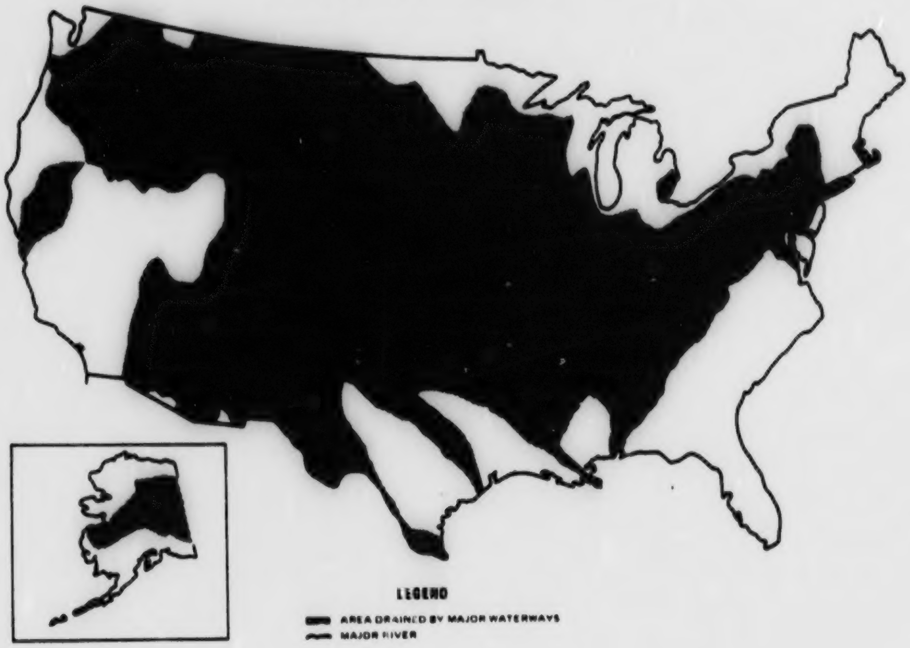
LEGEND
AREA DRAINED BY MAJOR WATERWAYS
MAJOR RIVER

Figure I-3

CITIES LOCATED ON MAJOR WATERWAYS

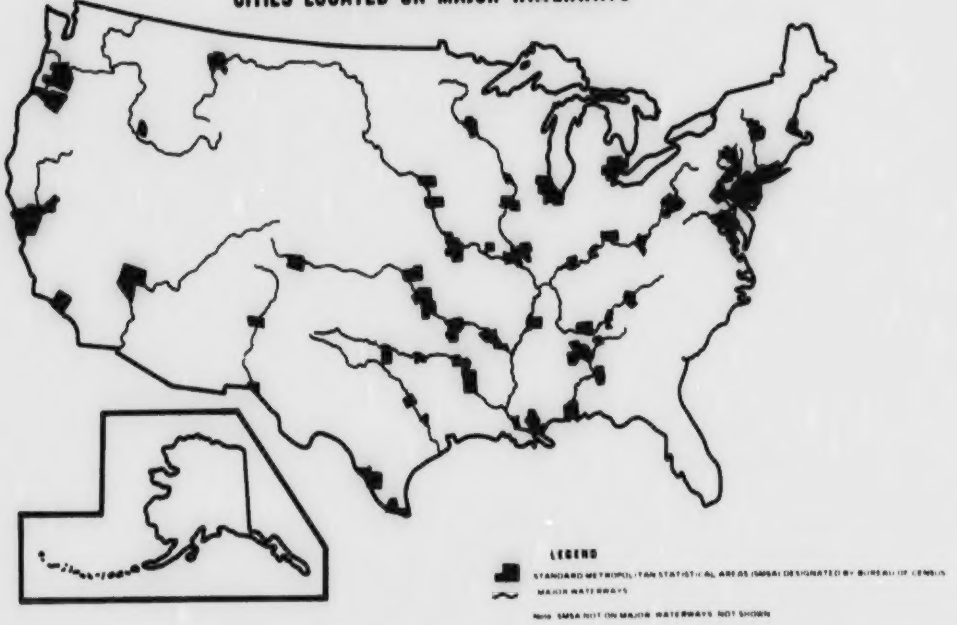
LEGEND
STANDARD METROPOLITAN STATISTICAL AREAS (SMSA) DESIGNATED BY BUREAU OF CENSUS
MAJOR WATERWAYS
Note: SMSA NOT ON MAJOR WATERWAYS NOT SHOWN

TABLE I-2

MAJOR WATERWAYS: POPULATIONS AND WATER SUPPLIES

Waterway	Population of drainage area* (thousands)	SMSA's on main stem	Population on main stem† (thousands)	Drinking water supplies from main stem‡	
				No.	Population served (thousands)
Hudson	16,192	3	11,464	1	60
Delaware	10,857	3	5,861	3	1,286
Susquehanna	3,413	6	1,939	2	133
Potomac	3,771	1	2,861	3	1,784
Alabama-Coosa	3,019	3	671	1	75
Ohio	20,364	8	5,527	18	3,174
Tennessee	3,216	3	933	3	432
Missouri	4,292	6	2,160	9	2,542
Mississippi	22,559	8	7,082	17	3,201
Arkansas	4,451	6	1,552	–	–
Red	1,732	4	607	–	–
Brazos	1,246	2	206	1	107
Rio Grande	2,970	5	1,070	5	347
Colorado	2,350	1	273	2	7,769
Sacramento	5,712	4	4,424	2	115
Columbia-Snake	2,170	1	112††	–	–
Willamette	1,501	4	1,409	1	27
Yukon	61	0	0	0	0
Boston Harbor	2,849	1	2,754	–	–
Chicago Metropolitan	(6,161)**	2	7,612	9	5,367
Detroit Metropolitan	4,707	3	4,552	7	2,162
Los Angeles Harbor	7,032	1	7,032	–	–
Total	124,464	75	70,101	84	28,581

*Source: EPA's National Planning Priorities Index, 1971.
†Source: Bureau of the Census, Department of Commerce.
‡Source: "Municipal Water Facilities – Communities of 25,000 Population and Over." DHEW, PHS, Jan. 1, 1964.
**Chicago SMSA included in Mississippi.
††Portland SMSA included in Willamette.

Water samples for routine monitoring are generally collected manually at each station – from a boat at a pre-selected site or from a bridge. In some cases, special studies or an intensive survey provide additional data. Each sample generally consists of one or two quarts of water. Some tests, such as temperature, pH, and dissolved oxygen, are performed immediately at the site, but most tests are made at central laboratories. For most samples, the process of collection, analysis, and data preparation for computer use takes only a few hours; when samples are combined into batches for processing, however, several weeks to a month are usually required to complete the cycle.

A total of 1,300 stations with over 1.2 million data values were used in the study of the 22 waterways (Table I-5). The selection of stations for analysis required two basic steps:

- Stations located on the main stems of the rivers (or in the waterway areas) were retrieved from STORET.
- Stations were discarded that had fewer than 10 observations of metals or complex organic compounds for the period 1963-72, and fewer than 20 observations of other parameters.

TABLE I-3

RESERVOIR STORAGE ON MAJOR WATERWAYS*
(January 1963)

Waterway	No. of reservoirs†	Storage (1,000 acre feet)
Hudson	0	0
Delaware	0	0
Susquehanna	3	498
Potomac	0	0
Alabama-Coosa	4	1,112
Ohio	0	0
Tennessee	10	13,849
Missouri	12	79,327
Mississippi	5	1,197
Arkansas	1	646
Red	1	5,530
Brazos	2	2,742
Rio Grande	3	5,820
Colorado	4	59,264
Sacramento	2	4,516
Columbia-Snake	16	10,577
Willamette	0	0
Yukon	0	0
Boston Harbor	0	0
Chicago Metropolitan	0	0
Detroit Metropolitan	0	0
Los Angeles Harbor	0	0
Total major waterways	63	192,997
Total, U.S.	1,562	359,360

*Source: *Reservoirs in the United States*, Geological Survey Water Supply Paper No. 1838.

†Number of reservoirs exceeding 5,000 acre-feet of storage.

For each station, three summary statistics were computed for each parameter:

- *Median*: the middle of the range of water quality measurements; 50 percent of the observations taken at a station fall on either side of the median. Also called the 50th percentile.

- *15th and 85th percentiles*: the range of values observed at a station, excluding extreme values; 70 percent of the values fall between the 15th and 85th percentiles. The 30 percent of observations that are higher than the 85th percentile and lower than the 15th percentile were excluded from the analysis because they often represent relatively transitory conditions and, in some instances, faulty data.

These summary statistics were computed for the 5-year periods 1968-72 and 1963-67; summer months (June-October); winter months (January-March); and other periods for which analysis was required. In some parts of the report the mean values, or averages, of several stations were computed. For parameters with sparse or scattered data, observations for all the stations on a stream reach were considered as a single station.

Appendix A is a bibliography of sources consulted for this report. Appendix B provides a list of the 1,300 STORET stations used.

TABLE I-4

MAJOR WATERWAYS: STREAM FLOWS AND DRAINAGE AREAS*

Waterway	Flow-measuring location	Drainage (square miles)	Years of record (as of 1960)	Period of record flow – cubic feet per second (as of 1960) †		
				Annual avg	Daily max flow	Daily min flow
Hudson	Green Island, N.Y.	8,090	14	13,930	141,000	1,270
Delaware	Trenton, N.J.	6,780	48	11,930	329,000	1,220
Susquehanna	Harrisburg, Pa.	24,100	70	34,590	740,000	1,600
Potomac	Point of Rocks, Md.	9,651	65	9,248	480,000	540
Alabama-Coosa	Near Mt. Vernon, Ala.	43,000	1	38,150	143,000	4,310
Ohio	Natrona, Pa.	11,410	22	19,570	238,000	922
	Cincinnati, Ohio	76,580	21	96,720	894,000	–
	Metropolis, Ill.	203,000	32	258,100	1,780,000	20,600
Tennessee	Knoxville, Tenn.	8,934	61	12,810	195,000	1,010
	Near Paducah, Ky.	40,200	71	63,790	500,000	150
Missouri	Williston, Mo.	164,500	42	25,040	231,000	1,320
	Omaha, Nebr.	322,800	32	28,280	396,000	2,200
	Hermann, Mo.	528,200	63	79,490	676,000	4,200
Mississippi	Royalton, Minn.	11,600	36	3,892	29,400	254
	St. Paul, Minn.	36,800	62	9,833	125,000	632
	Alton, Ill.	171,500	33	93,130	437,000	7,960
	Near Vicksburg, Miss.	1,444,500	32	559,500	2,080,000	99,400
Arkansas	Witchita, Kan.	40,420	26	1,100	30,000	3
	Little Rock, Ark.	158,201	33	41,880	536,000	850
Red	Gainesville, Tex.	30,782	24	3,197	168,000	48
	Alexandria, La.	67,500	32	32,390	233,000	873
Brazos	Waco, Tex.	28,500	62	2,539	246,000	0
Rio Grande	Brownsville, Tex.	182,215	26	2,729	31,700	0

TABLE I-4–(Continued)

MAJOR WATERWAYS: STREAM FLOWS AND DRAINAGE AREAS*

Waterway	Flow-measuring location	Drainage (square miles)	Years of record (as of 1960)	Period of record flow–cubic feet per second (as of 1960) †		
				Annual avg	Daily max flow	Daily min flow
Colorado	Lees Ferry, Ariz.	107,900	49	17,980	220,000	750
	International Border near San Luis, Ariz.	243,000	10	3,659	28,610	0
Sacramento	Sacramento, Calif.	–	12	23,620	104,000	5,590
Columbia-Snake	Dalles, Oreg.	237,000	82	195,360	1,240,000	35,000
	Clarkston, Wash.	103,200	10	54,400	199,300	19,210
Willamette	Wilsonville, Oreg.	8,400	12	30,110	248,000	3,600
Yukon	Kaltag, Ala.	296,000	4	187,700	1,020,000	–
Boston Harbor	–	–	–	–	–	–
Chicago Metropolitan	–	–	–	–	–	–
Detroit Metropolitan	Detroit, Mich.	–	20	200,000	240,000	100,000
Los Angeles Harbor	–	–	–	–	–	–

*Source: U.S. Geological Survey

†Average or extreme flows may be different in future due to reservoir construction before or after 1960. For example, maximum flows of Missouri River occurred before major reservoir construction.

TABLE I-5

MONITORING STATIONS, PARAMETERS, AND OBSERVATIONS*

(1963-72)

Waterway	No. of stations	No. of parameters	No. of analytical tests
Hudson	31	42	45,158
Delaware	105	40	112,696
Susquehanna	39	47	22,438
Potomac	88	40	77,305
Alabama-Coosa	27	25	35,288
Ohio	54	39	81,352
Tennessee	184	39	102,724
Missouri	25	43	49,033
Mississippi	99	41	116,969
Arkansas	46	37	69,107
Red	24	34	24,714
Brazos	18	31	18,959
Rio Grande	22	34	25,256
Colorado	57	32	43,654
Sacramento	24	39	7,747
Columbia-Snake	89	41	69,967
Williamette	39	33	115,885
Yukon	7	12	2,037
Chicago Metropolitan	206	42	170,926
Detroit Metropolitan	109	35	52,802
Boston Harbor	7	7	959
Los Angeles Harbor	0	0	0
Total	1,300	47	1,244,976

*An additional 41 metal and pesticide parameters had 86,298 analytical tests.

This analysis of the 22 major waterways is a first step toward understanding the quality of the Nation's navigable waters. While this type of analysis provides a good overview of water quality, it does not attempt to portray local conditions, or to analyze local problems, because:

- Data from local intensive surveys are not available uniformly throughout the 22 waterways. Where they are available, there are usually not enough samples for trend analysis.
- Routine monitoring stations are generally not spaced closely enough to pinpoint exact locations of trouble spots or to find individual sources.
- Inventories of point sources are generally available, but nonpoint sources are not yet inventoried.
- Laboratories contributing data to STORET may apply differing analytical methods and differing degrees of quality control. Although such instances do not significantly affect general overviews, they can distort local details.
- The types of parameters measured at a station often change to reflect new pollution problems, so trend analyses are not always possible at every station. Overview analyses are not generally affected by these local gaps because they rely on many stations spread over longer stream reaches.

In short, the report focuses on a broad overview, rather than local details.

POLLUTANTS ANALYZED*

Although STORET contains measurements of over 1,500 different physical and chemical parameters, even these would be insufficient to describe completely the quality of a body of water. To do so would entail chemical analyses of a near-infinite number of solid, liquid, and gaseous compounds, as well as a complete identification of all biota present in the water from viruses to vertebrates. Thus, any practical description of water quality can only be concerned with a very limited subset of all conceivable physical, chemical, and biological aspects of waterbodies. Typical water quality measurements are, in fact, oriented toward a small group of commonly observed pollution problems.

Harmful Substances

A stream of seemingly clean and pure water may be highly polluted due to the presence of toxic substances in very low concentrations. For example, certain chemicals in concentrations of only several micrograms per liter (μg/l) may be deadly to the mayfly, an important link in the aquatic food chain. Certain harmful substances may be natural, such as acids from bogs. Most, however, are man-made, such as chemicals used in industry and agriculture. A few of these are well-known–heavy metals, pesticides, and polychlorinated biphenyls (PCB's), for example.

Toxicity effects can be dramatic, as in the case of large fishkills, or they can be subtle, as in the case of minute concentrations causing decreasing fertility or changing reproductive or predation habits over a long period of time. Detecting any chemical and tracing it back to its sources can be difficult, particularly in the case of widely used and highly persistent substances such as mercury, dieldrin, or PCB's. Sources can be diverse, ranging from industrial or municipal sewage discharges to urban stormwater, agricultural runoff, or atmospheric particle "fallout". It is therefore not safe to assume that the only major sources of harmful substances are industrial discharges.

Analysis of these harmful substances is complicated because they do not usually remain dissolved or suspended in water but are taken up by sediments, plants, and animals. In the case of DDT, concentrations in fish will be at least one order of magnitude greater than in sediments, which in turn have concentrations at least one order of magnitude greater than the overlying waters. Since most other important pesticides are insoluble (and many toxic metals form relatively insoluble salts), water concentrations by themselves do not form reliable indicators. For the same reasons, water concentrations will tend to be very low–in the μg/l range–making results extremely sensitive to the specific chemical analysis methods used. For instance, older gas chromatographic methods for DDT were unable to distinguish DDT clearly from PCB's. Since PCB's are often found in substantially higher concentrations than DDT, these older results are quite unreliable.

Physical Modification

Aquatic habitats are sensitive to fluctuations of many physical characteristics of water, including temperature and transparency. Temperature fluctuations occurring naturally can be amplified by human activities through large discharges of industrial cooling water (such as from power plants or steel mills), from release of warm surface water held in reservoirs, or from destruction of shade trees along stream banks. Warm discharges do not automatically cause ecological damage–some even increase desirable biological activity. Large thermal discharges into small or relatively stagnant bodies of water, however, can cause large temperature increases. If such increases occur in critical "zones of passage" or spawning grounds, they can disrupt important biological communities.

Natural waters lose transparency due to suspended sediment loads and plankton concentrations. Aside from natural sources of sediment there are human sources, including construction activities, strip mining, and farming practices. Transparency can also be lost by excess plankton growth, suspended organic material stimulated by nutrient-rich agricultural runoff, urban stormwater or sewer overflows, and sewage treatment plant discharges. Reduced transparency has a serious effect other than aesthetic degradation: It reduces the amount of light available to underwater plants and thus decreases a primary food source for aquatic organisms.

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*Most of the information on pollutants was prepared by Enviro Control, Inc.

Another significant alteration of key aquatic habitats results from physical modification of shores, banks, and channels. Artificial draining of marshland to create waterfront property destroys the highly productive environment necessary for spawning of certain fish species and feeding of migratory birds. Construction of breakwaters can reduce "flushing" of bays to the point where the effect of pollutant discharges to these bays is greatly magnified by stagnant water conditions. Channel and watershed "improvement" destroys biological communities on stream banks and, in some cases, can accelerate erosion and sediment production.

Finally, dams and their impoundments can produce profound long-term changes in the physical and biological characteristics of a stream. These changes include beneficial as well as negative effects.

Not all aspects of physical modifications of streams and estuaries are quantifiable. In fact, only a few simple measures of the extent of harmful physical modifications (including suspended solids, turbidity, color, and temperature) are known. Some other physical measures that would be useful are often not routinely made; among these are sediment cores to analyze the nature of bottom deposit buildup, and settleable solids to measure the materials deposited on the bottom.

Eutrophication Potential

An adequate crop of algae is the beginning of the food chain for most aquatic communities. However, relatively stagnant waters (such as lakes and slow-moving estuaries) rich in nutrients can grow such heavy crops of algal and other aquatic plants that daily respiration depletes dissolved oxygen. Ultimately the decay of dead cell matter may seriously deplete the bottom waters of oxygen. This affects the survival of oxygen-sensitive species. In extreme cases, floating algal mats, thick bottom slimes, and odors result.

All lakes, as part of a natural aging process, gradually become more eutrophic over many thousands of years as sediments and nutrients wash into the lake. Artificial addition of any one of the 100 or so nutrients necessary to plant growth may accelerate the natural processes and stimulate algal blooms (heavy growths) in waters where that nutrient is normally under-supplied. In addition to the well-known nutrients, phosphorus and nitrogen, there are others equally essential to plants, including carbon dioxide, iron, potassium, magnesium, and vitamins. Man adds nutrients to water by many means. Perhaps one of the most important sources is runoff of agricultural fertilizers, which yield large loads of phosphorus, nitrogen, and potassium; other sources include treated municipal sewage, industrial discharges, and sewer overflows.

The only direct measure of eutrophication is a biological study of the waters in question. Indirect measures of eutrophication are biomass, standing algal crops, chlorophyll, nutrient balance, and benthic (that is, stream or lake bottom) oxygen demand. Unfortunately, most of these are almost never monitored routinely. Nutrient levels can be useful, although not necessarily conclusive, measures of the potential for eutrophication. Of the 100 or so nutrients essential for plant growth, only compounds of nitrogen and phosphorus are routinely measured, making it difficult to use normal monitoring evidence to specify the direct cause of a bloom.

Salinity, Acidity, and Alkalinity

Major changes in the salt content of water can seriously disrupt aquatic communities and decrease the value of water for irrigation and water supply purposes. Where the fresh water inflow of estuaries is reduced through upstream consumption or diversion of freshwater, the saline front advances upstream. This advance decreases the low salinity area of the estuary necessary for spawning or growth of important species such as striped bass. Furthermore, it reduces the fresh water available for water supplies.

Many inland streams are naturally saline, due to the salt content of solids and minerals in their drainage basins. In certain areas, this natural salinity has been substantially increased by man's activities. Irrigation in saline soil areas increases stream salinity, because of increased evaporation (both on land and in reservoirs) and leaching of salt from the soil into the irrigation return flow. In certain basins, mine and quarry drainage can also add substantial salt loads to rivers.

Acidity changes can be equally damaging to aquatic life. The most important acid sources are industrial discharges, drainage from mines, and acid rain downwind from major sulfur-polluted air regions. The importance of sulfur air pollution has only recently been recognized; several small lakes have suffered such serious increases in acidity within only one decade as to almost eliminate many desirable fish species. Highly acidic industrial and municipal discharges that are large relative to the receiving stream can also cause damage.

Alkalinity presents problems in many areas, particularly west of the Mississippi River. The problems range from reduced agricultural production to the fouling of water pipes. Most alkaline pollutants are from natural sources such as sodium carbonate deposits. However, certain industries may also contribute to an alkaline condition.

Quantitative analysis of salinity normally uses total dissolved solids as an indicator of total salts; common individual salts such as sulfates and chlorides are also sometimes measured. To some extent, specific ecological damage due to salinity depends on the composition of the salts present. Acidity/alkalinity measures are considerably more complex. pH, the measure of free hydrogen ions present, determines the stream's net acidity or alkalinity: a pH of from 0 to 7 indicates net acidity, while a pH of 7 to 14 indicates net alkalinity. A value of 7 indicates neutral water. Alkalinity measures the stream's capacity to buffer acids, and acidity measures the capacity to buffer bases. Thus, if a given stream shows little pH trend over the last 10 years, but alkalinity has decreased markedly, one can predict that the stream will be considerably more vulnerable to relatively small acid discharges.

Oxygen Depletion

Oxygen dissolved in water is one of many substances essential to sustaining aquatic animal life. The dissolved oxygen (DO) level is widely considered to be the single most important indicator of pollution; actually, there is no reason to consider it more or less important than indicators such as toxicity, salinity, and algal population.

Dissolved oxygen is consumed whenever any substance is oxidized in water. This oxidation can be a direct chemical process or it can be a biological process. Aquatic communities from bacteria to fish consume dissolved oxygen in metabolizing food substances. Such food substances range from sugars and starches, which are consumed by microorganisms in days, to paper pulp or oils, which are consumed by microorganisms only after months. Rapidly consumable substances create oxygen deficits within a few days of stream travel from their sources, while slowly consumable substances create deficits weeks or months later.

Thus, slowly consumable substances may not cause significant oxygen loss in the stream at all; instead, they may be consumed in a downstream lake, reservoir, estuary, or ocean where they may or may not pose a problem. The rate of consumption for a specific food substance or waste is highly sensitive to temperature; higher water temperatures greatly accelerate the growth and metabolism of the microorganisms that feed on the waste. On the other hand, many toxic substances slow this growth and can give a misleading picture of oxygen sufficiency.

Oxygen-demanding substances can be attributed to many sources. There are large natural sources, including leaves, soil organic matter, and wildlife droppings washed into rivers by storm runoff. Agricultural areas contribute additional runoff-carried oxygen demand from lifestock manure and topsoil erosion. There are also point sources: municipal sewage treatment plant discharges and a wide variety of industrial waste discharges. However, some urbanized areas contribute oxygen-demanding loads by other routes, including storm sewers, sewer overflows, intentional treatment plant bypasses, sewer leaks, and unsewered runoff.

The direct quantitative measures of oxygen content of water are the absolute concentration of DO present, and the percent of saturation for DO corrected for temperature and atmospheric pressure (since warm or low pressure water can dissolve less oxygen than cold or high pressure water). Supersaturated values commonly approach 140 percent in waters where algae contribute substantial oxygen during the daytime.

In describing the oxygen-depleting characteristics of wastes, 5-day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) are the most common measures. Each has drawbacks. In BOD_5, the waste or stream sample is incubated in a bottle (sometimes inoculated with stream microorganisms) at 20°C. for 5 days, and the amount of oxygen metabolically consumed by the microoganisms is measured. Among the many deficiencies of the BOD_5 measurement are: It has very poor repeatability; bottle conditions are far from stream conditions; trace toxicants can seriously inhibit microorganism growth and reduce apparent oxygen demand; and the 5-day reading gives no indication of depletion rate over shorter or longer periods. In measurement of COD, a sample of water is chemically oxidized to give an approximate upper bound on the amount of nonvolatile oxidizable material present; COD cannot be measured in salty water, however, and it also fails to capture the volatile oxidizable substances such as organic acids, alcohols, and ammonia which are often the most important determinant of short-term oxygen levels.

Health Hazards and Aesthetic Degradation

An assessment of health hazards from polluted water involves considerable uncertainty. There is little doubt that human feces carry infectious pathogens for a number of diseases, including typhoid fever, hepatitis, brucellosis, encephalitis, poliomyelitis, psittacosis, and tuberculosis. However, there are uncertainties about the die-off rates of pathogens in natural waters as well as their infectiousness for swimmers or other recreational water users. The issue of drinking water is generally not at stake, since its safety depends on disinfection and treatment by the water supply system. The evidence that water polluted with fecal matter can transmit diseases to swimmers is sparse and uncertain, particularly since it has been discovered that swimmers in unpolluted water also have higher incidences of common ear, eye, and nose infections. There is some evidence that hepatitis can be transmitted via shellfish from polluted waters; unfortunately, the usual antibacterial measure—chlorination of sewage effluents—may not abate this problem for viral forms of hepatitis.

The evidence for waterborne toxicity hazards via fish, shellfish, and perhaps drinking water is somewhat stronger, at least in the case of relatively high concentrations of mercury and cadmium. On the other hand, considerably less effort has been expended on the chronic health hazards of low-level, long-term toxicants in drinking water (and fish) than on the infectious disease problem. Consequently, little can be said in this area, since specific tests are usually not available.

Despite the paucity of evidence regarding waterborne transmission of diseases to recreational users, public health agencies since the turn of the century have assumed that the problem exists. Because of the complexity of identifying specific pathogens in water, these agencies traditionally have used several indirect and nonspecific measures of bacterial populations in water: total coliforms, fecal coliforms, and fecal streptococci. These bacteria are not necessarily pathogenic, nor do they simulate the die-off rates of pathogens. Fecal bacterial counts are sometimes good indicators of the presence of undisinfected municipal sewage, when runoff sources are either low or insignificant. Unfortunately, fecal coliforms are also found in runoff from agricultural and wilderness lands and from urban areas. In fact, it is possible that some types of fecal coliforms can multiply significantly in streams under certain conditions.

Water bodies can be degraded aesthetically by increases in turbidity, color, algal scums, floating solids and oils, and odors. Algal growth has been discussed under Eutrophication Potential. Floating solids and oils, in areas with properly functioning treatment plants and oil separators, generally come from combined sewer overflows, storm sewer discharges, unsewered runoff, and bottom scour, as evidenced by the major increases in these measures directly after rainstorms. Unaesthetic odors can stem from many sources, including decaying organic matter in water or on the bottom and a myriad of industrial chemicals. Among chemicals, phenols are traditionally singled out for special attention by pollution control agencies.

In the broad area of health hazards and aesthetic degradation, only a few measures are routinely monitored. The ones available for analysis are total coliform, fecal coliform, fecal streptococci, phenols, and odor.

II. QUALITY OF 22 WATERWAYS

The data in EPA's water quality information system, STORET, provide an overview of the physical and chemical quality of the 22 waterways described in Chapter I. Six key pollution problems–harmful substances, physical modification, eutrophication potential, salinity/acidity/alkalinity, oxygen depletion, and health hazards and aesthetic degradation–are analyzed to measure trends during the past decade, and to determine the effects of seasonal and hydrologic variations. Two major categories of harmful substances–metals and pesticides–are discussed, but there are not enough data to measure trends and variations.

For the overview analysis, the 22 waterways are divided into 36 reaches (Table II-1). Twelve waterways are studied as single reaches. Eight rivers are so long that it is necessary to subdivide them into two or more reaches: the

TABLE II-1

REACHES STUDIED ON 22 WATERWAYS

Reach	Description
Hudson River	Entire river
Delaware River	Entire river
Susquehanna River	Entire river
Potomac River	Entire river
Alabama-Coosa Rivers	Entire river
Upper Ohio River	Headwaters to Greenup Dam
Middle Ohio River	Below Portsmouth, Ohio to Brandenburg, Ky.
Lower Ohio River	Owensboro, Ky. to Cairo, Ill.
Upper Tennessee River	Headwaters of the N. Fork of the Holston River to Guntersville, Ala.
Lower Tennessee River	Whitesburg, Ala. to Mile 22
Upper Missouri River	Headwaters to Yankton, S.D.
Middle Missouri River	Sioux City, Iowa to Kansas City, Mo.
Lower Missouri River	Missouri City, Mo. to St. Louis, Mo.
Upper Mississippi River	Headwaters to Anoka, Minn.
Mississippi River near Minneapolis	Stations in Minneapolis area
Middle Mississippi River	Minneapolis, Minn. to Cape Girardeau, Mo.
Lower Mississippi River	Hickman, Ky. to New Orleans, La.
Upper Arkansas River	Headwaters to Mile 594
Lower Arkansas River	Mile 530 to Mile 24
Upper Red River	Headwaters to Mile 777
Lower Red River	Mile 704 to Mile 100
Brazos River	Entire river
Rio Grande River	Entire river
Upper Colorado River	Headwaters to Mile 895
Lower Colorado River	Mile 710 to Mile 1
Sacramento River	Entire river
Columbia River	Entire river
Snake River	Entire river
Willamette River	Entire river
Yukon River	Entire river
Boston Harbor	Harbor area
Chicago Area-Tributaries	Chicago area tributaries to Lake Michigan and the Illinois River
Chicago Area-Lake Michigan	Lake Michigan in Chicago area
Detroit Area-Tributaries	Detroit area tributaries to Detroit and St. Clair Rivers, and Lakes Erie and St. Clair
Detroit Area-Rivers	Detroit and St. Clair Rivers
Los Angeles Harbor	Harbor area

Mississippi River is divided into four reaches, the Missouri and Ohio into three, and the Arkansas, Colorado, Red, Tennessee, and Columbia-Snake into two each. Data for Chicago and Detroit are subdivided into two sets each.

Several special statistics are computed for use in this chapter:

- For each pollutant, a reach is characterized by averaging the medians for all stations into a single number: the mean of the medians. For convenience, this number is referred to as the *median* of the reach. Each station receives equal weighting, and all reaches are considered equally. Some stations had longer periods of record than others; some measured as many as 40 parameters, and some far fewer.
- Trends are determined for a reach by comparing the median for 1968-72 with that for 1963-67: if the first median is higher than the second, an upward trend is said to occur.
- Seasonal variations are determined by comparing the winter (January-March) median with that for summer (June-October).
- To determine the relative quality of water, values were compared with uniform *reference levels*, such as the 4.0 mg/l for dissolved oxygen suggested in EPA's 1973 *Guidelines for Developing or Revising Water Quality Standards*. If the dissolved oxygen median was less than 4.0, the reach would be said to violate the reference level. These reference levels are for comparative purposes, and are not to be construed as new standards or guidelines.

TRENDS

The data examined show a mixed picture for the 22 waterways, but suggest that the impact of improving effluent treatment for BOD_5, COD, bacteria, ammonia, and suspended solids is beginning to be apparent; these pollutants all showed general improvements (Table II-2).

Worsening trends are associated with nutrients–forms of nitrogen and phosphorus; other parameters with high levels are phenols, suspended solids, and coliform bacteria (Table II-3). The worsening trends in nutrient parameters may be related to effluent controls, since reduction of oxygen demand by secondary waste treatment is often accomplished at the expense of increasing nitrogen and phosphorus.

- *Physical Modification.* About four-fifths of the reaches show improved suspended solids and turbidity median levels for 1968-72 compared to 1963-67. On the other hand, color improved in only 33 percent of the reaches. In 14 percent of the reaches, median suspended solids exceed 80 milligrams per liter (mg/l), a reference level associated with protection of fish; 28 percent of reaches exceed a turbidity reference level of 50 Jackson units. Many of the high levels arise from natural causes.
- *Eutrophication Potential.* The nutrients most often blamed for accelerating eutrophication–nitrates and phosphorus–show generally worsening trends, although few of the rivers studied had evidence of algae blooms.* Median concentrations increased in 1968-72 over 1963-67 in 82 percent of reaches for total phosphorus, 74 to 76 percent for nitrates, and 56 percent for total phosphates. On the other hand, dissolved phosphates improved in 56 percent of reaches. In addition, 24 percent of the reaches exceed a nitrate reference level of .9 mg/l associated with nuisance algae, 57 percent exceed the total phosphorus reference level (0.1 mg/l), 41 percent exceed the total phosphate reference level (0.3 mg/l), and 22 percent exceed the dissolved phosphate reference level (.3 mg/l).

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*Increasing nutrient levels are less likely to cause algae blooms in large, free-flowing rivers than in lakes or impoundments because such factors as turbidity and stream velocity inhibit such growths. However, increasing nutrients in streams are of concern because they can affect the balance of biota in a stream, they can accumulate in estuaries, and they can be indicative of high concentrations in upstream areas where conditions are more conducive to algae blooms.

TABLE II-2

MAJOR WATERWAYS: WATER QUALITY TRENDS, 1963-72*

Parameter	No. reaches analyzed	% of reaches improved†
Suspended solids	28	82
Turbidity	29	79
Fecal coliforms (membrane filter)	9	78
Ammonia	25	76
BOD_5	31	74
Total coliforms (membrane filter delayed)	23	70
COD	20	70
Temperature	33	67
Total coliforms (most probable number)	9	67
Dissolved solids (105°C)	28	64
Chlorides	34	62
Dissolved oxygen	31	61‡
Dissolved solids (180°C)	23	61
Odor	5	60
pH	34	59**
Total coliforms (membrane filter immediate)	12	58
Phenols	12	58
Dissolved phosphate	18	56
Sulfates	33	55
Organic nitrogen	11	55
Total phosphate	16	44
Alkalinity	32	41‡
Nitrite	5	40
Nitrite plus nitrate	27	37
Color	30	33
Nitrate (as NO_3)	19	26
Nitrate (as N)	17	24
Total phosphorus	28	18

*Based on median values at each reach. Reaches included only if they contain one or more stations with at least seven samples each. Parameters included only if five or more reaches were measured.

†Except where noted, "improved" means that 1968-72 median concentrations are lower than 1963-67 median concentrations at mean station.

‡"Improved" means higher concentrations.

**"Improved" means pH becomes higher (less acid).

- *Salinity, Acidity, and Alkalinity.* Salinity and acidity show generally improved levels in 1968-72 over 1963-67. Dissolved solids and chlorides improved in 61 to 64 percent of the reaches, depending on the parameter measured. From 9 to 18 percent of reaches exceed reference levels for water supplies (500 mg/l for dissolved solids, 250 mg/l for chlorides and sulfates), but many of these include naturally saline segments that are not used for water supply. pH and alkalinity show no strong trends in the reaches as a whole, with median pH well within the 6.0-9.0 reference range on all reaches.

- *Oxygen Depletion.* The measures of oxygen depletion generally improved: 74 percent of reaches show lower BOD_5 in 1968-72 than in 1963-67; 70 percent show lower COD; and 61 percent show higher dissolved oxygen. No reach fell below a median dissolved oxygen reference level of 4.0 mg/l. Ammonia, a nitrogen compound that exerts an oxygen demand, improved in 76 percent of reaches.

- *Health Hazards and Aesthetic Degradation.* Total and fecal coliform bacteria, while generally improving, continue to exceed reference levels in 13 to 43 percent of reaches. From 58 to 78 percent of reaches show lower coliform levels in 1968-72, depending on the parameter used. A total coliform reference level of 10,000 organisms per 100 ml is exceeded in 13 to 30 percent of reaches; the fecal coliform reference level of 2,000 organisms per 100 ml is exceeded in 21 to 43 percent of reaches. Phenols, industrial compounds that add odor to fish flesh and drinking water, exceed a reference level of 0.001 mg/l in 71 percent of reaches, an improvement from 1963-67 (86 percent).

If the percentage of parameters exceeding reference levels is used to represent the degree of pollution on a reach, more rivers were moderately polluted in 1968-72 than in 1963-67, but fewer rivers were highly polluted. More reaches showed a small percentage of parameters exceeding reference levels, but fewer reaches showed a relatively high percentage of parameters exceeding (Table II-4).

The 36 reaches can be ranked according to the number of parameters that exceeded reference levels (Table II-5). The ranking is more an indicator of relative water quality than of man-made pollution, since the effects of naturally occurring impurities and man-made effluents are not separated. The quality of a reach may be a result of any combination of point discharges, nonpoint sources, or natural conditions. The method for achieving the ranking is explained in Appendix H.

SEASONAL AND HYDROLOGIC VARIATIONS

The concentrations of most water quality parameters are strongly affected by seasonal and hydrologic variations. Temperature changes affect chemical and biological reaction rates, and streamflow variations affect dilution rates, erosion and bottom scour, and correlate with surface runoff. For this study, 30 river reaches were analyzed to determine the degree and pattern of variations during different periods of the year–January-March (winter) and June-October (summer). Of the 30 reaches, 20 have higher flows in the winter months than summer, while 10 have higher flows in summer.

The results of the analysis show that more reaches exceed reference levels for suspended solids, nitrogen, dissolved solids, and phenols in winter than in summer, while total and fecal coliforms show the reverse pattern (Table II-6). Seasonal oxygen demand and nutrient levels seem to be related primarily to temperature, while those of solids seem to be related primarily to flow (Table II-7).

TABLE II-3

MAJOR WATERWAYS: REFERENCE LEVEL VIOLATIONS, 1963-72

		% of reaches exceeding reference levels		
Parameter	Reference level and source	1963-72	1968-72	Change
Suspended solids	80mg/1–aquatic life+	26	14	-12
Turbidity	50JU–aquatic life*	28	28	0
Temperature	90°F–aquatic life*	0	0	0
Color	75 platinum-cobalt units–water supply+	0	0	0
Ammonia	0.89mg/l–aquatic life+	16	6	-10
Nitrate (as N)	0.9mg/l–nutrient††	12	24	+12
Nitrite plus nitrate	0.9mg/1–nutrient††	18	26	+ 8
Total phosphorus	0.1mg/l–nutrient*	34	57	+23
Total phosphate	0.3mg/l–nutrient*	30	41	+11
Dissolved phosphate	0.3mg/l–nutrient*	11	22	+11
Dissolved solids (105°C)	500mg/l–water supply*	25	18	-7
Dissolved solids (180°C)	500mg/l–water supply*	28	12	-16
Chlorides	250mg/l–water supply+	12	9	-3
Sulfates	250mg/l–water supply+	12	12	0
pH	6.0-9.0–aquatic life*	0	0	0

TABLE II-3 (Continued)

Parameter	Reference level and source	% of reaches exceeding reference levels 1963-72	1968-72	Change
Dissolved oxygen	4.0mg/l–aquatic life*	0	0	0
Total coliforms(MFD)**	10,000/100ml–recreation*	24	13	-11
Total coliforms(MFI)**	10,000/100ml–recreation*	50	30	-20
Total coliforms (MPN)**	10,000/100ml–recreation*	23	20	-3
Fecal coliforms (MF)**	2,000/100ml–recreation*	45	21	-24
Fecal coliforms (MPN)**	2,000/100ml–recreation*	17	43	+26
Phenols	0.001mg/l–water supply+	86	71	-15

***Guidelines for Developing or Revising Water Quality Standards*, EPA Water Planning Division, April 1973.

+*Criteria for Water Quality*, EPA, 1973 (Section 304(a)(1) guidelines).

††*Biological Associated Problems in Freshwater Environments*, FWPCA, 1966, pp 132-3.

**Membrane filter delayed, membrane filter immediate, most probable number, membrane filter.

TABLE II-4

MAJOR WATERWAYS: TRENDS IN DEGREE OF POLLUTION

% of parameters exceeding reference levels	1963-67 (number of reaches)	1968-72
0 to 7	14	13
greater than 7 to 17	7	12
over 17	13	10
No. reaches with data	34	35

TABLE II-5

MAJOR WATERWAY RANKINGS*

Upper Third	Middle Third	Lower Third
Upper Missouri River	Rio Grande River	Hudson River
Columbia River	Alabama-Coosa Rivers	Delaware River
Lower Tennessee River	Upper Ohio River	Middle Mississippi River
Snake River	Susquehanna River	Lower Arkansas River
Willamette River	Upper Red River	Lower Ohio River
Boston Harbor	Lower Colorado River	Lower Mississippi River
Upper Mississippi River	Potomac River	Middle Ohio River
Yukon River	Detroit Area–Tributaries	Lower Missouri River
Chicago Area-Lake Michigan	Scaramento River	Chicago Area–Tributaries
Upper Tennessee River	Lower Red River	Mississippi near Minneapolis
Detroit Area–Rivers	Brazos River	Upper Arkansas River
	Upper Colorado River	Middle Missouri River

*Based on the number of parameters having medians which exceed reference levels selected for comparative purposes. Parameters measure in-stream water quality which results from point sources, nonpoint sources, and natural sources. Los Angeles Harbor not ranked because of lack of data.

TABLE II-6

MAJOR WATERWAYS: SEASONAL REFERENCE LEVELS EXCEEDED, 1968-72

Parameter	% of reaches exceeding reference levels*		
	Winter	Summer	Difference
Suspended solids	18	12	-6
Turbidity	28	29	+1
Temperature	0	0	0
Color	0	0	0
Ammonia	7	3	-4
Nitrate (as N)	28	19	-9
Nitrite plus nitrate	50	32	-18
Total phosphorus	58	52	-6
Total phosphate	37	40	+3
Dissolved phosphate	14	12	2
Dissolved solids (105°C)	25	15	-10
Dissolved solids (180°C)	25	15	-10
Chlorides	12	12	0
Sulfates	12	12	0
pH	0	0	0
Dissolved oxygen	0	0	0
Total coliforms (MFD)†	4	22	+18
Total coliforms (MFI)†	41	41	0
Total coliforms (MPN)†	8	15	+7
Fecal coliforms (MF)†	23	24	+1
Fecal coliforms (MPN)†	20	33	+13
Phenols	89	72	-17

*Reference levels shown in Table II-3.

†Membrane filter delayed, membrane filter immediate, most probable number, membrane filter.

- *Physical Modification.* Suspended solids exceed reference levels on more reaches in winter (18 percent) than summer (12 percent), while turbidity exceeds reference levels to about the same degree in both seasons (28 and 29 percent). Both parameters seem to be dominated by flow-related effects, such as runoff and bottom scour, since concentrations are higher in the higher-flow season for 13 reaches, but higher in the lower-flow season for 5 reaches.

- *Eutrophication Potential.* The seasonal data show that the phosphorus and inorganic nitrogen parameters are worse in winter for most of the reaches, while the organic nitrogens are worse in summer for most of the reaches. Since the pattern occurs regardless of the flow regimes of the reaches, it is probably the temperature and related biological differences between the seasons that account for the pattern in most reaches: biological activity stimulated by higher temperatures in the summer may be causing the nutrient forms to be consumed and organic nitrogen to be produced. Of the two nutrients, phosphorus is of greater immediate concern, because more reaches violate phosphorus reference levels than nitrogen reference levels, regardless of season.

TABLE II-7

MAJOR WATERWAYS: SEASONAL AND FLOW ANALYSIS, 1968-72

Parameter	Pollutant levels worse in: winter, high flow	summer, low flow	winter, low flow	summer, high flow	Dominant effect
	(number of reaches)				
Suspended solids	9	5	0	4	High flow
Turbidity	13	4	1	7	High flow
Color	11	6	3	4	High flow
Ammonia	14	3	7	1	Cold weather
Nitrite	3	7	5	1	Low flow
Nitrate (as N)	12	4	8	1	Cold weather
Nitrate (as NO_3)	8	3	6	1	Cold weather
Nitrite plus nitrate	2	3	2	1	Inconclusive
Organic nitrogen	3	6	0	3	Warm weather
Total Kjeldahl nitrogen	3	5	0	3	Warm weather
Total phosphorus	10	3	5	2	Cold weather
Total phosphate	8	3	5	1	Cold weather
Dissolved phosphate	6	3	4	0	Cold weather
Dissolved solids (105°C)	4	7	6	3	Low flow
Dissolved solids (180°C)	3	8	6	2	Low flow
Chlorides	4	15	10	0	Low flow
Sulfates	5	13	5	5	Warm weather, low flow
Alkalinity	6	12	10	0	Low flow
pH	15	4	6	4	Cold weather, high flow
Dissolved oxygen	0	19	0	9	Warm weather
BOD_5	11	6	8	1	Cold weather
COD (.025N)	6	5	3	2	Cold weather
Total coliforms (MFD)*	4	10	2	5	Warm weather
Total coliforms (MFI)*	8	6	2	4	High flow, warm weather
Total coliforms (MPN)*	4	2	3	3	Inconclusive
Fecal coliforms (MF)*	6	6	3	4	Inconclusive
Fecal coliforms (MPN)*	4	0	1	0	Cold weather
Phenols	5	0	1	0	Inconclusive
Odor	4	0	0	0	Inconclusive

*Membrane filter delayed, membrane filter immediate, most probable number, membrane filter.

- *Salinity, Acidity, and Alkalinity.* Dissolved solids exceed reference levels on more reaches in winter (25 percent) than in summer (15 percent); chlorides, sulfates, and pH show about the same percent of violations in winter and summer. Dissolved solids are dominated by low-flow effects, since concentrations are higher in the lower flow season for 13 or 14 reaches, but higher in the higher-flow season for 5 to 7 reaches.

- *Oxygen Depletion.* The oxygen parameters appear to be dominated by temperature-related effects. Dissolved oxygen levels are worse in summer than in winter for every reach studied, reflecting the lower solubility of gases in warm water, as well as the increased oxygen consumption of organisms at higher temperatures. BOD_5 and COD levels tend to be higher in winter than summer in the majority of reaches, indicating the lower activity of microorganisms in winter, as well as other seasonal effects.

- *Health Hazards and Aesthetic Degradation.* More reaches exceed total and fecal coliform bacteria reference levels in summer than winter, although the results are somewhat ambiguous because of the different ways bacteria are measured. For instance, at stations using membrane filter tests (MF), winter-summer violations are approximately equal (23 to 24 percent), while stations using the most-probable-number analysis (MPN) show 33 percent violations in summer, compared to 20 percent in winter. More detailed analysis of flow and temperature effects was generally inconclusive.

METALS AND PESTICIDES

While metals and pesticides are potentially harmful in water, laboratory methods are not always capable of detecting the exact quantities present. For instance, dissolved solids present in a water sample interfere with the spectrographic procedure used extensively for metals; when interference occurs, the procedure cannot provide an exact measurement and must be discarded for trend or seasonal analysis. As a result, 23 percent of metals samples and 15 percent of pesticide samples could not be used. (Trends and other statistics could have been computed using the remaining samples with no interferences, but the results would have been misleading, since there is no evidence that the interferences occur randomly). There are enough data, however, to give a general indication of the number of reaches where metals and pesticides have been found in concentrations exceeding reference levels.

Metals

For metals, the percentage of usable samples varies widely, from 22 percent for beryllium to 98 percent for boron (Table II-8). Besides beryllium, four other metal parameters (dissolved chromium, total chromium, total mercury and silver) had about one half or more of their samples unusable.

Five metals exceeded reference levels related to drinking water supplies in half or more of the reaches where they were measured in the 1968-72 period: iron (30 reaches), manganese (26), cadmium (17), lead (16), and mercury (15). Cadmium, lead, and mercury would be of the most concern from a health standpoint if the waterways are used for water supply intakes; the data should be used with caution, however, since interferences prevent exact measurements for these three metals parameters in 27 to 41 percent of samples.

Pesticides

For pesticides, the percentage of usable samples is generally very high, with no pesticide showing less than 76 percent of samples usable, and the herbicides showing no interferences at all.

Nine pesticides were detected in half or more of the reaches where they were measured (Table II-9): DDT (22 of 24 reaches), dieldrin (19 of 24), DDE (16 of 23), BHC (12 of 19), DDD (10 of 20), diazinon (9 of 16), and all three herbicides—2,4-D (14 of 17 reaches), 2,4,5-T (13 of 17 reaches), and Silvex (10 of 17 reaches). Reference levels were exceeded in most reaches where herbicides were detected.

The data for metals and pesticides highlight the need for more controlled analyses in order to detect trends and seasonal relationships. In addition, systematic samples from sediments and from animal tissues would be particularly useful to determine the degree to which metals and pesticides are available for accumulation in the food chain.

DETAILED DATA

The remainder of this chapter is devoted to presenting seasonal and trend data for each river reach. Each page presents the detailed data behind a parameter selected from among those discussed in this chapter (Figures II-1 through II-36).

These pages present the ranges of the observed values of various parameters, both within a waterway and among the waterways, in summer, winter, and each of the two 5-year intervals 1968-72 and 1963-67.

TABLE II-8

MAJOR WATERWAYS: METALS LEVELS, 1968-72*

Metal (dissolved)	Total reaches sampled	Reaches with at least one usable measurement	Reaches with at least one usable measurement above reference level	% of samples usable	Reference level (micrograms per liter)
Aluminum (total)	28	23	3	67	5,000††
Arsenic	31	29	4	84	100†
Barium	30	30	1	97	1,000†
Beryllium	28	14	0	22	100†††
Boron	30	30	4	98	1,000†
Cadmium	31	29	17	72	10†
Chromium	29	26	3	41	50†
Chromium (hexavalent)	23	19	3	94	50†
Chromium (total)	25	20	8	29	50†
Copper	31	30	5	77	1000†
Iron (total)	33	33	30	96	300†
Lead	31	29	16	73	50†
Manganese (total)	33	31	26	94	50†
Mercury	20	18	5	71	2†
Mercury (total)	29	28	15	53	2†
Nickel	31	24	6	67	200†††
Silver	31	23	0	42	50†

*Of 53,594 samples, 77 percent produced usable measurements.

†Water Supply – *Criteria for Water Quality*, EPA, 1973 (Section 304(a)(1) guidelines).

††Livestock – *Ibid.*

†††Irrigation – *Ibid.*

TABLE II-9

MAJOR WATERWAYS: PESTICIDE LEVELS, 1968-72*

Pesticide	Total reaches sampled	Reaches with at least one usable measurement	Reaches with at least one usable measurement above reference level	Reaches with at least one usable measurement above zero	Reference level (micrograms per liter)
Aldrin	24	21	1	9	1††
BHC	22	19	†	12	†
Chlordane	23	19	0	2	3††
DDD	24	20	†	10	†
DDE	26	23	†	16	†
DDT	27	24	0	22	50††
Dieldrin	26	24	1	19	1††
Endrin	23	20	†	5	†
Heptachlor	24	21	0	5	0.1††
Heptachlor epoxide	23	20	0	4	0.1††
Malathion	18	16	†	1	†
Parathion	18	16	†	1	†
Diazinon	17	16	†	9	†
Methyl parathion	18	16	†	1	†
2,4-D	17	17	13	14	0.02††
2,4,5-T	17	17	13	13	0.002††
Silvex	17	17	5	10	0.03††

*Of 9,218 samples, 85 percent produced usable measurements, ranging from 76 percent for Heptachlor to 100 percent for 2, 2,4,5-T and Silvex.

†No reference level used.

††Water Supply – *Criteria for Water Quality*, EPA, 1973 (Section 304(a)(1) guidelines).

The lowest 15th percentile to the highest 85th percentile illustrate the range of values that differentiate between, for example, the Yukon River and the Alabama, or between the Mississippi in Minnesota and the Mississippi at New Orleans.

Generalizations will doubtless suggest themselves to each reader. Some of the more obvious inferences that may be drawn are:

- The South-Central rivers–Middle and Lower Mississippi, Arkansas, Red, Brazos, Rio Grande and Upper Colorado–are more turbid and show much larger variations in turbidity than the other waterways.
- The Western waterways tend to be more alkaline than the Eastern waterways, although the Willamette River has the lowest alkalinity of all the waterways.
- The South-Central rivers also are relatively higher in solids and total phosphorus than the other waterways.
- The Upper Arkansas, Upper Red, and Brazos rivers have the hardest waters of all the waterways; the Willamette has the least hard water.
- The Potomac, Mississippi at Minneapolis, and the Chicago and Detroit tributaries generally have the highest BOD_5; the Detroit River, the Lower Colorado, and Lake Michigan the lowest.

Figure II-1 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

WATER TEMPERATURE - °C

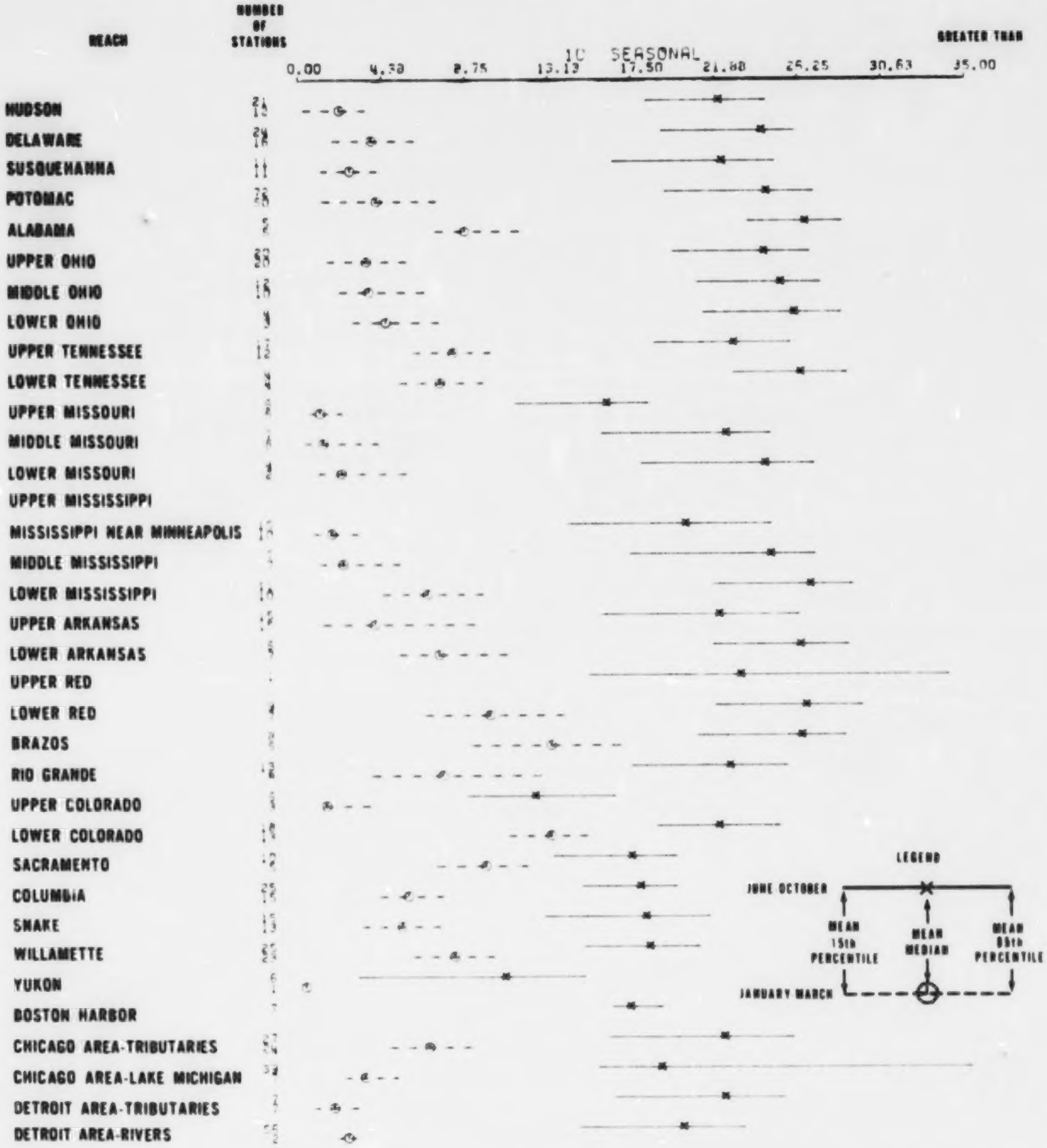

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Figure II-2 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

WATER TEMPERATURE-°C

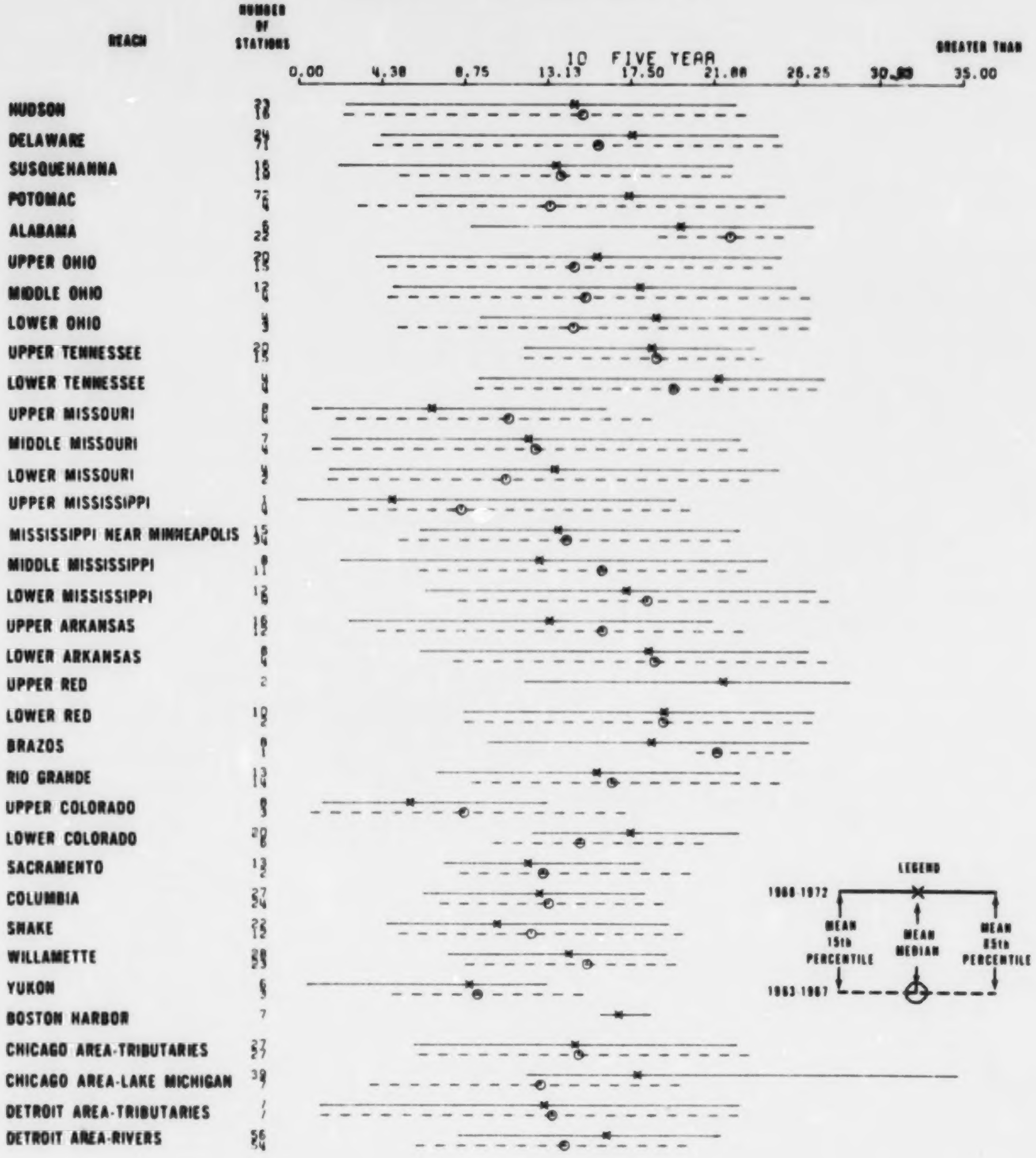


Figure II-3 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

MEAN DAILY STREAM FLOW-CUBIC FEET PER SECOND (× 100)

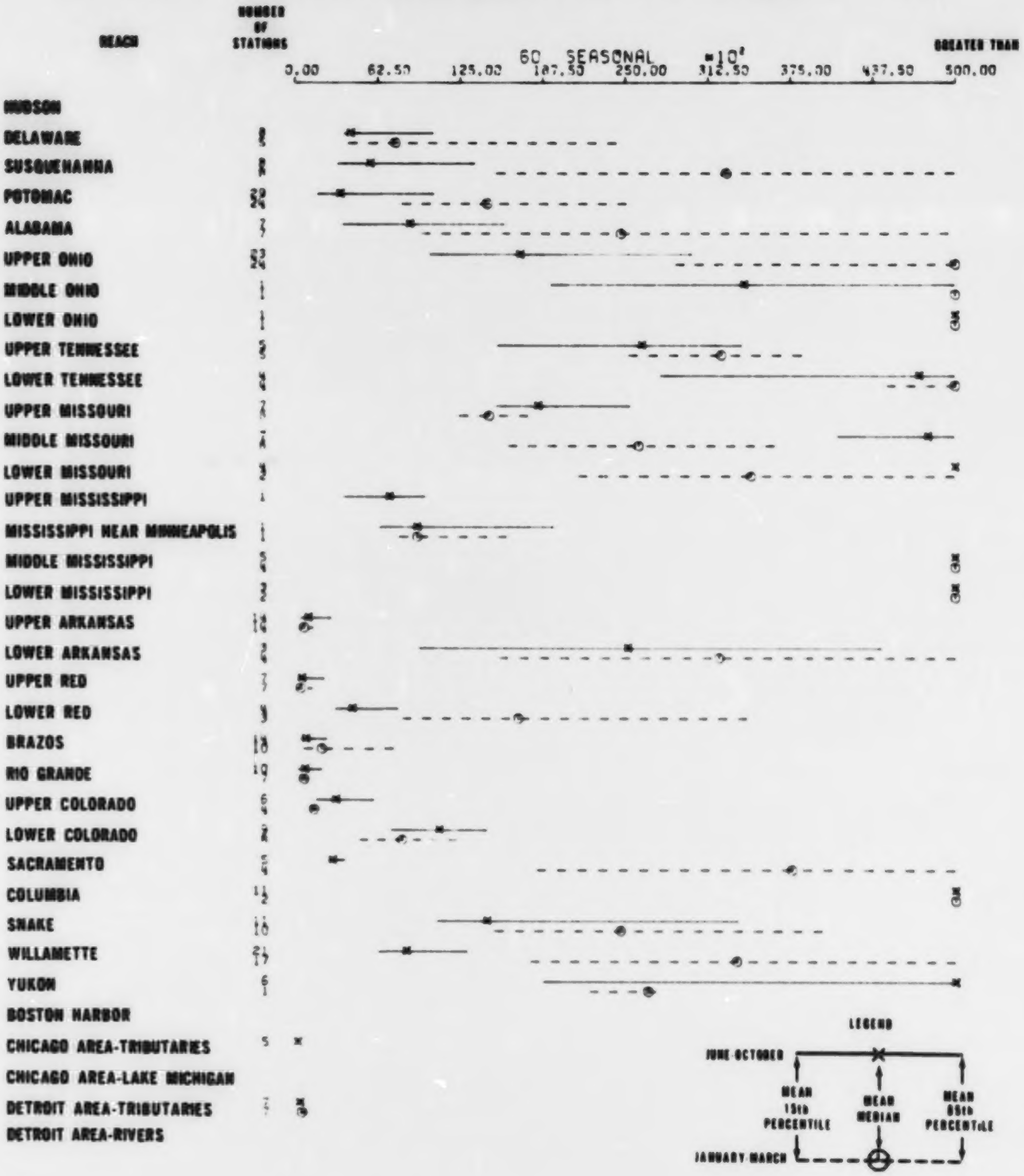


Figure II-4 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

MEAN DAILY STREAM FLOW-CUBIC FEET PER SECOND (× 100)

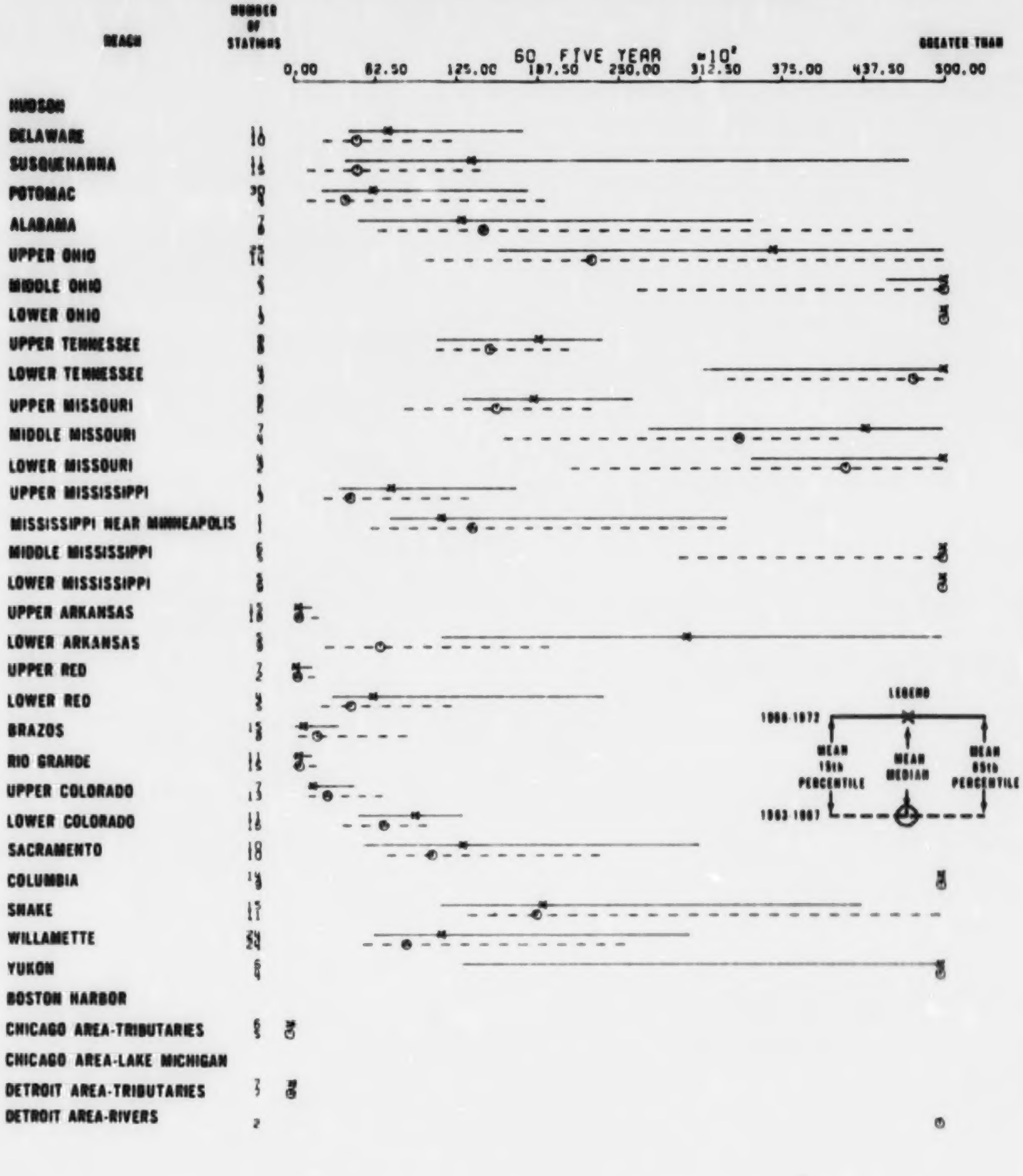


Figure II-5 MEAN PERCENTILES BY SEASON, 1968-72
22 MAJOR WATERWAYS
TURBIDITY-JACKSON CANDLE UNITS

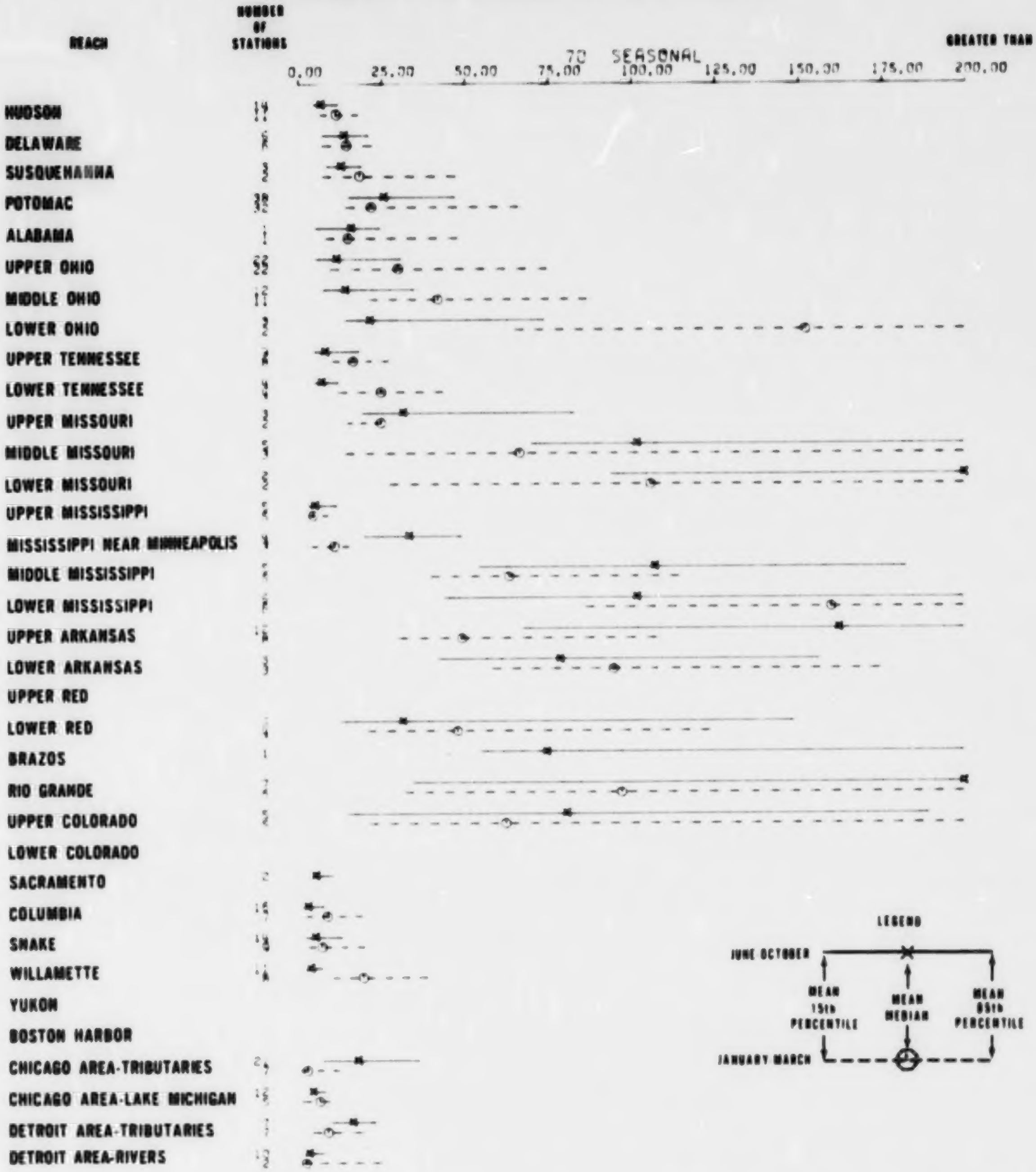


Figure II-6 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TURBIDITY-JACKSON CANDLE UNITS

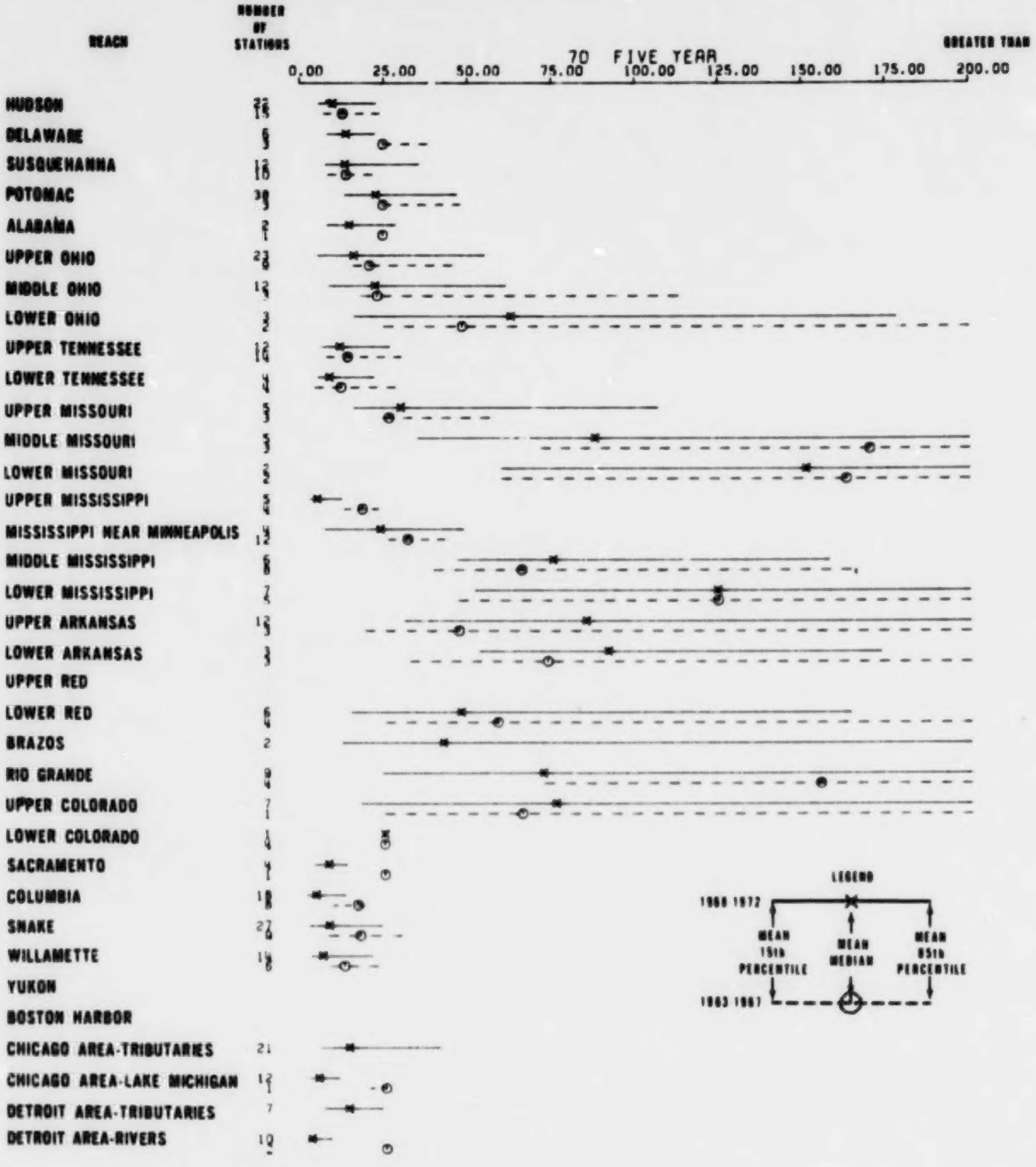


Figure II-7 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

COLOR - PLATINUM-COBALT UNITS

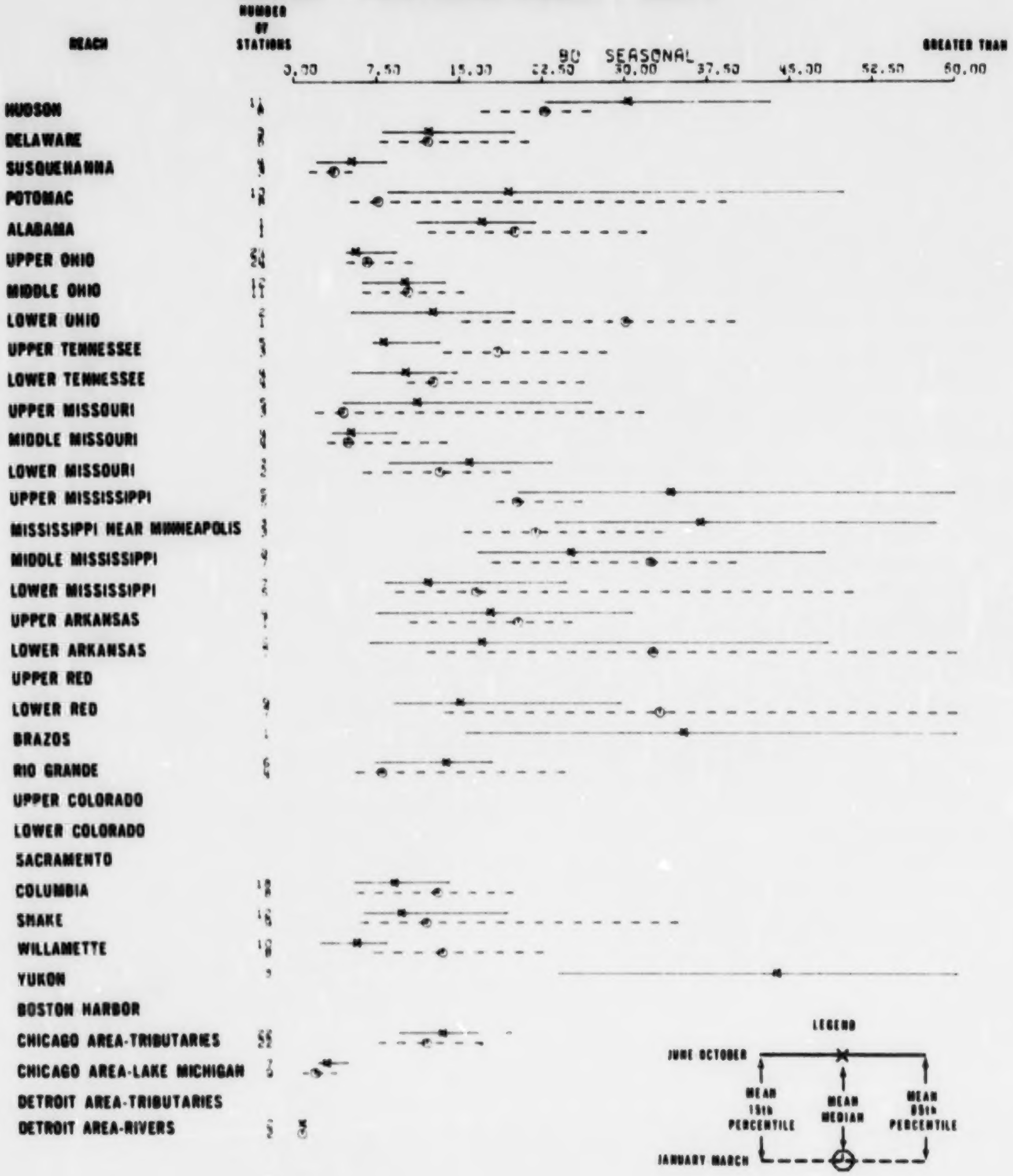


Figure II-8 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

COLOR - PLATINUM-COBALT UNITS

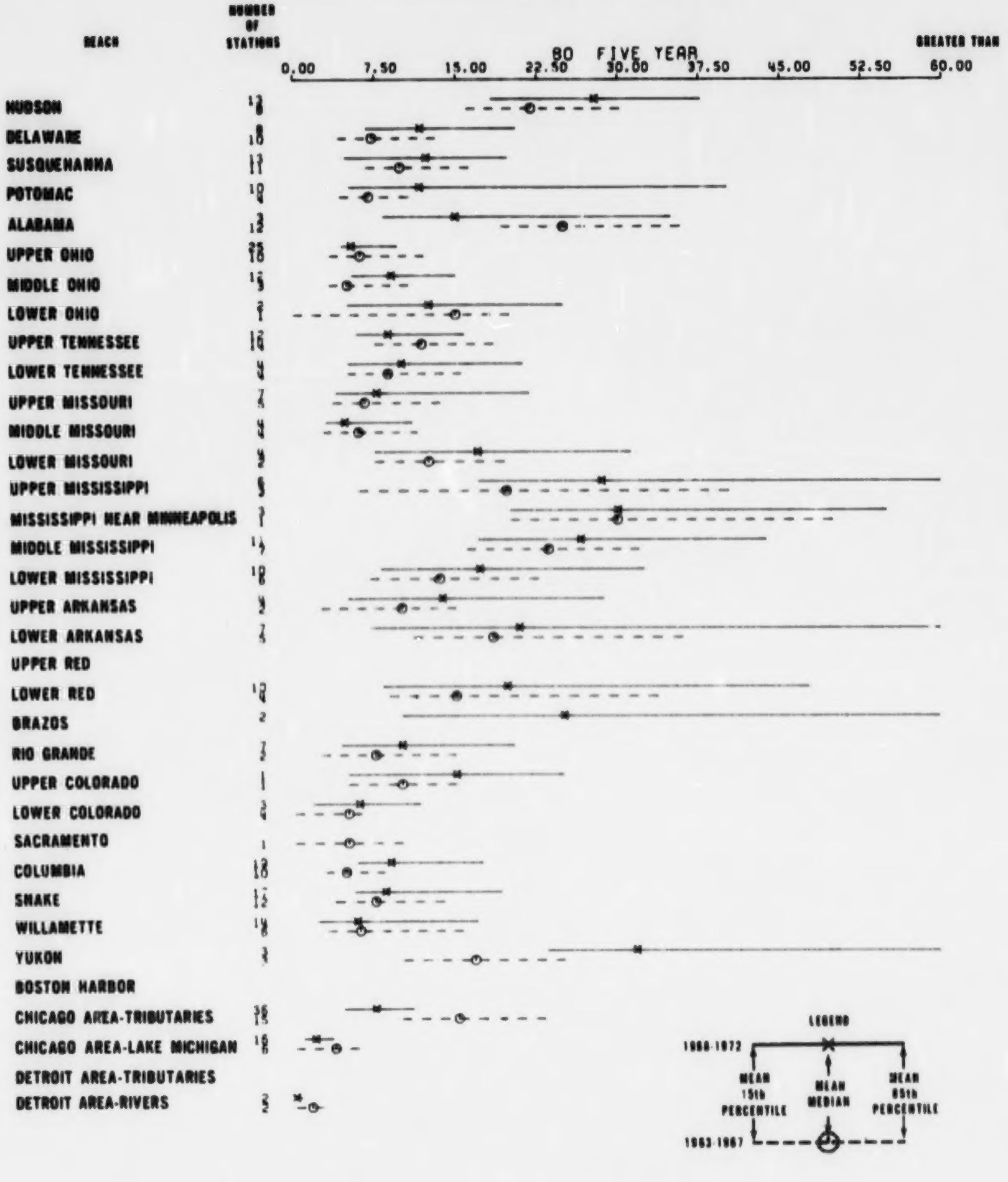


Figure II-9 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

DISSOLVED OXYGEN-mg/ℓ

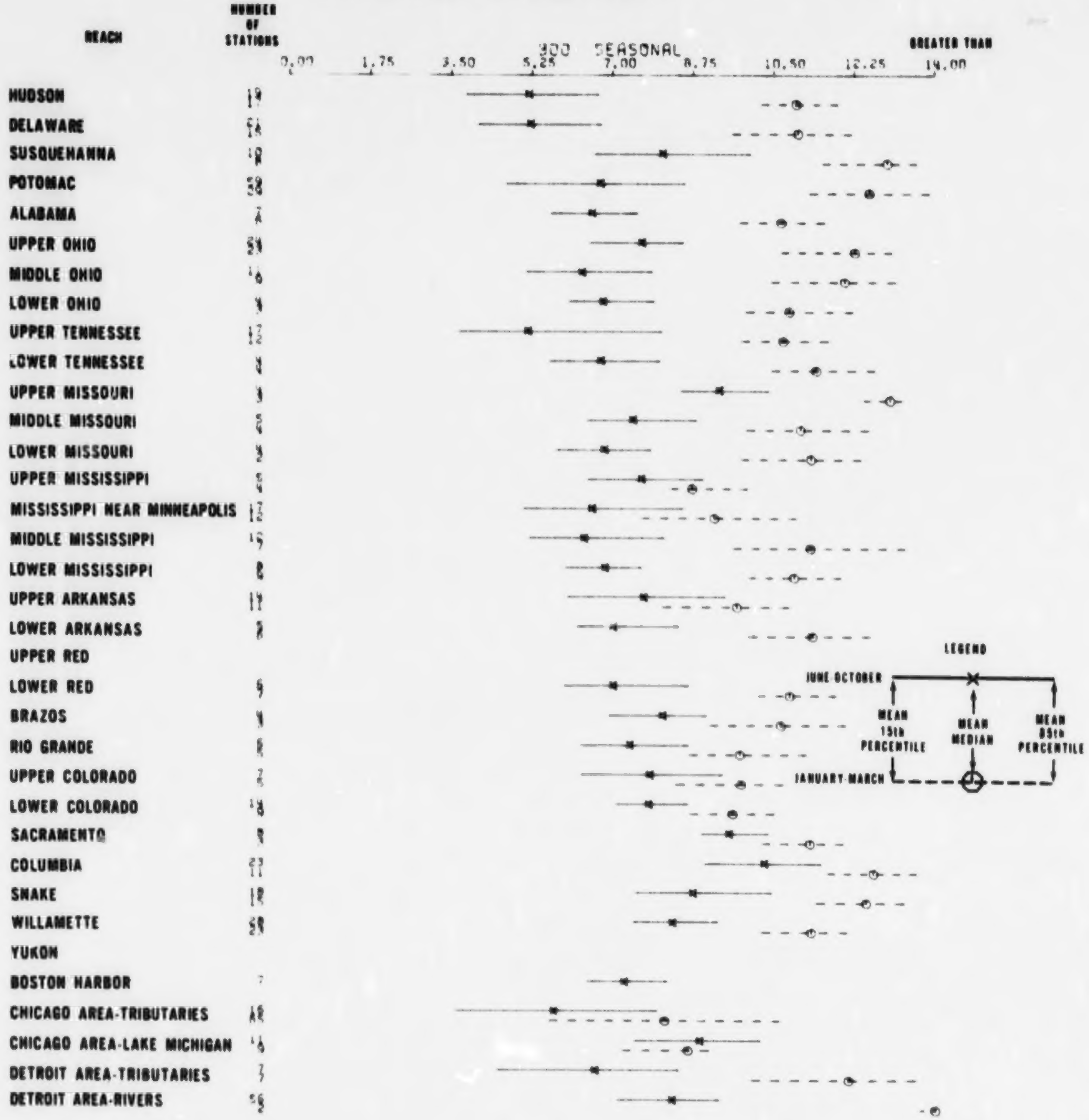


Figure II-10 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

DISSOLVED OXYGEN-mg/ℓ

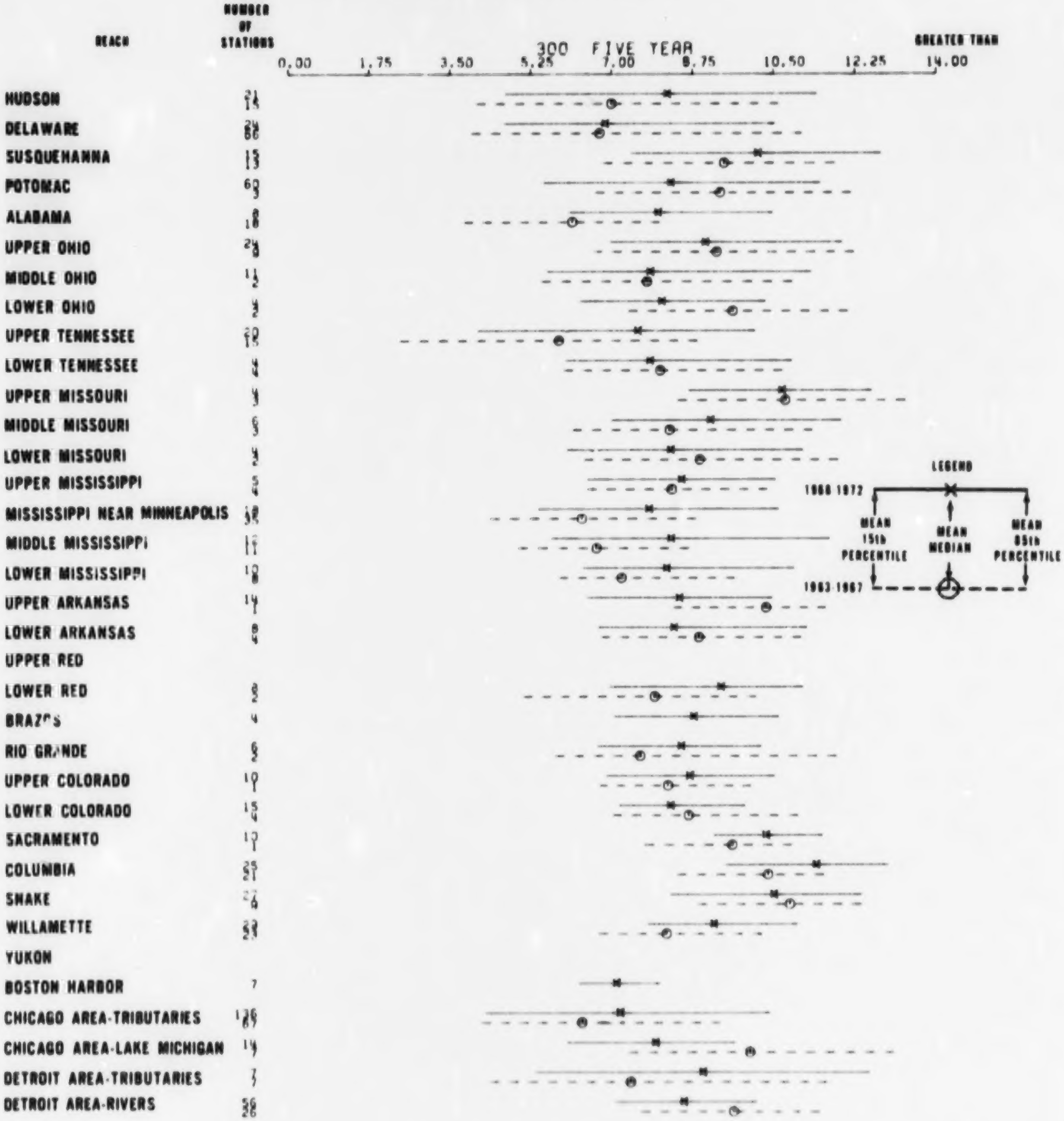


Figure II-11 MEAN PERCENTILES BY SEASON, 1968-72
22 MAJOR WATERWAYS
BIOCHEMICAL OXYGEN DEMAND (5 DAY)-mg/ℓ

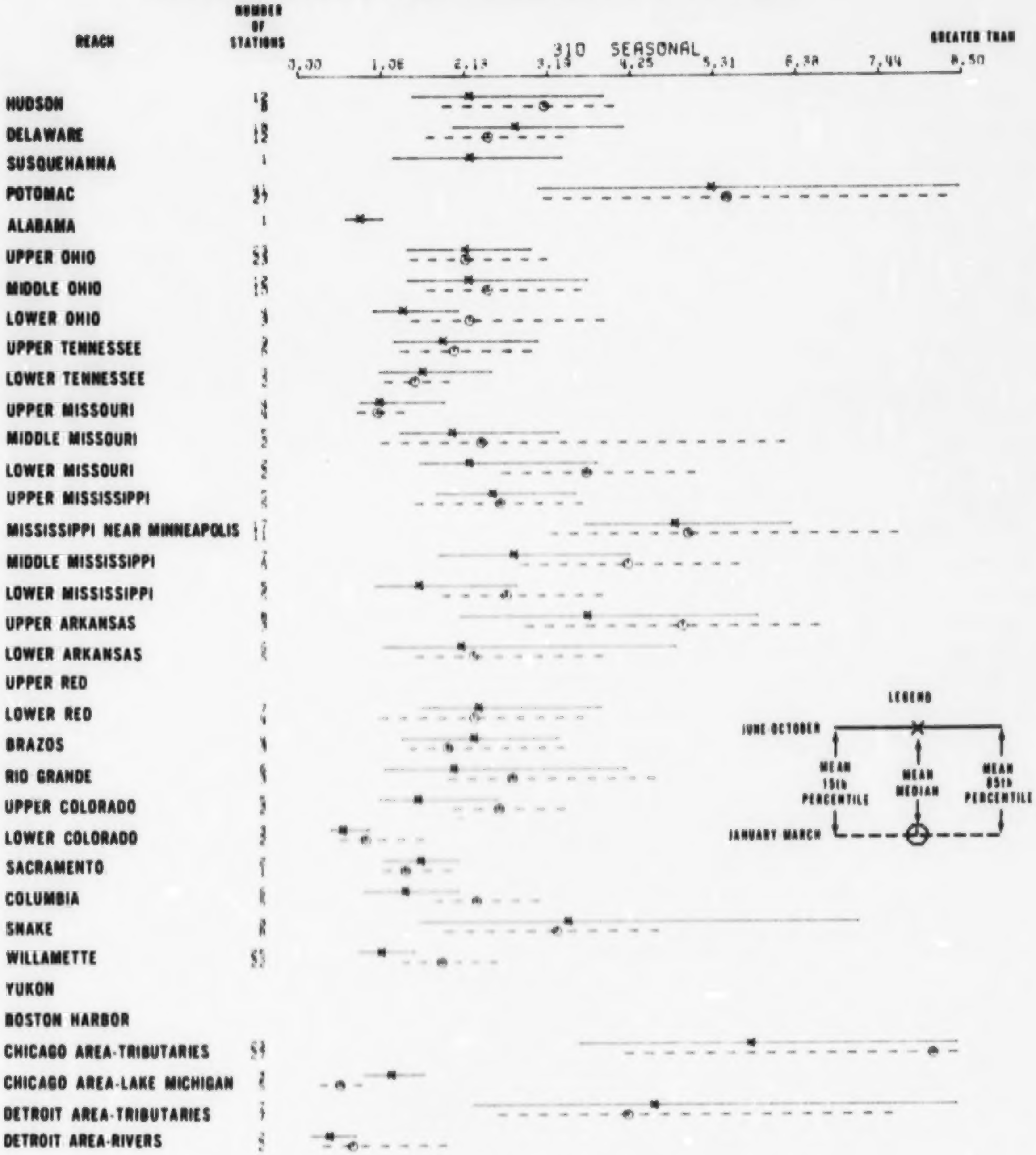


Figure II-12 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

BIOCHEMICAL OXYGEN DEMAND (5 DAY) -mg/ℓ

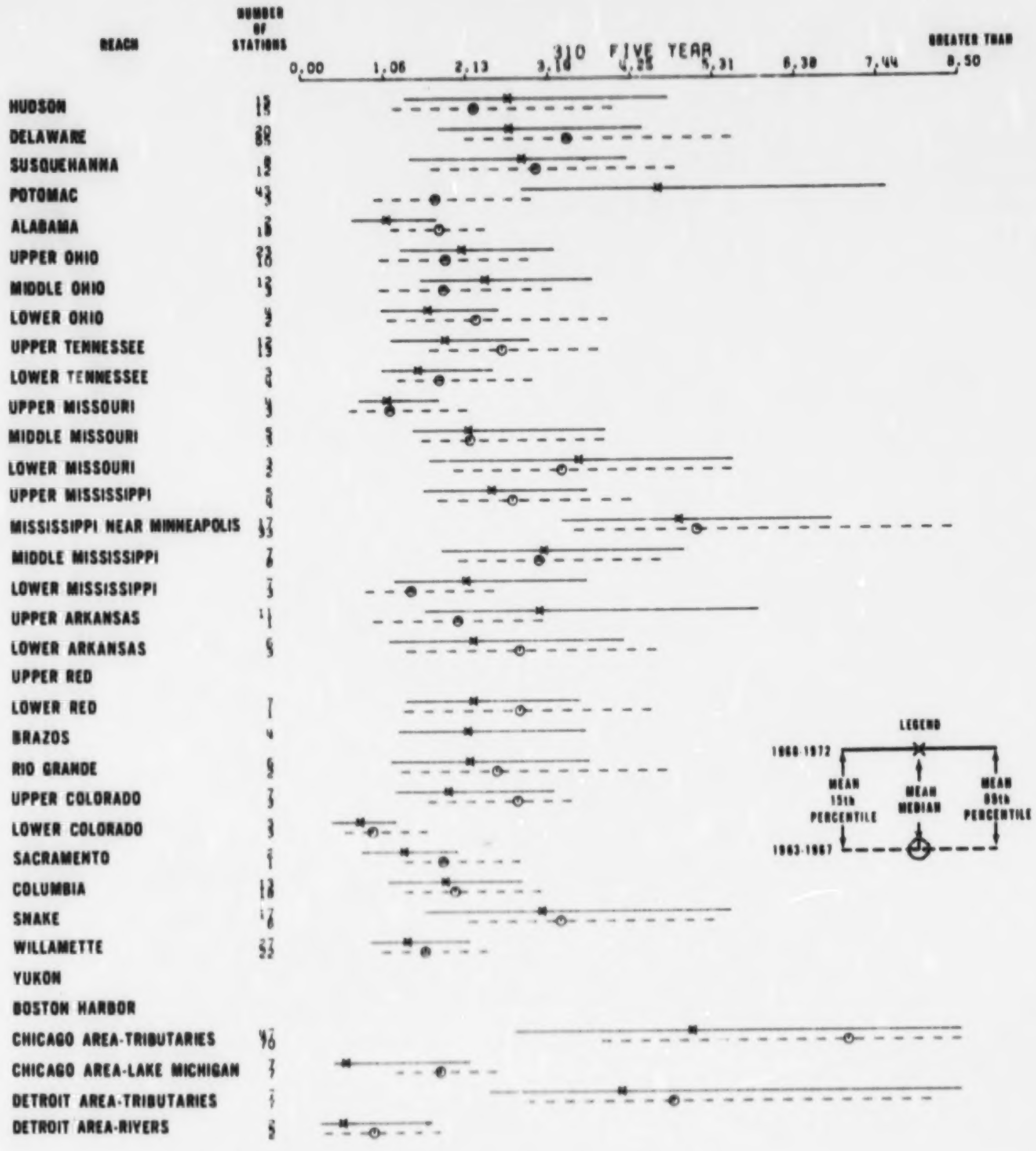


Figure II-13 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

pH-STANDARD UNITS

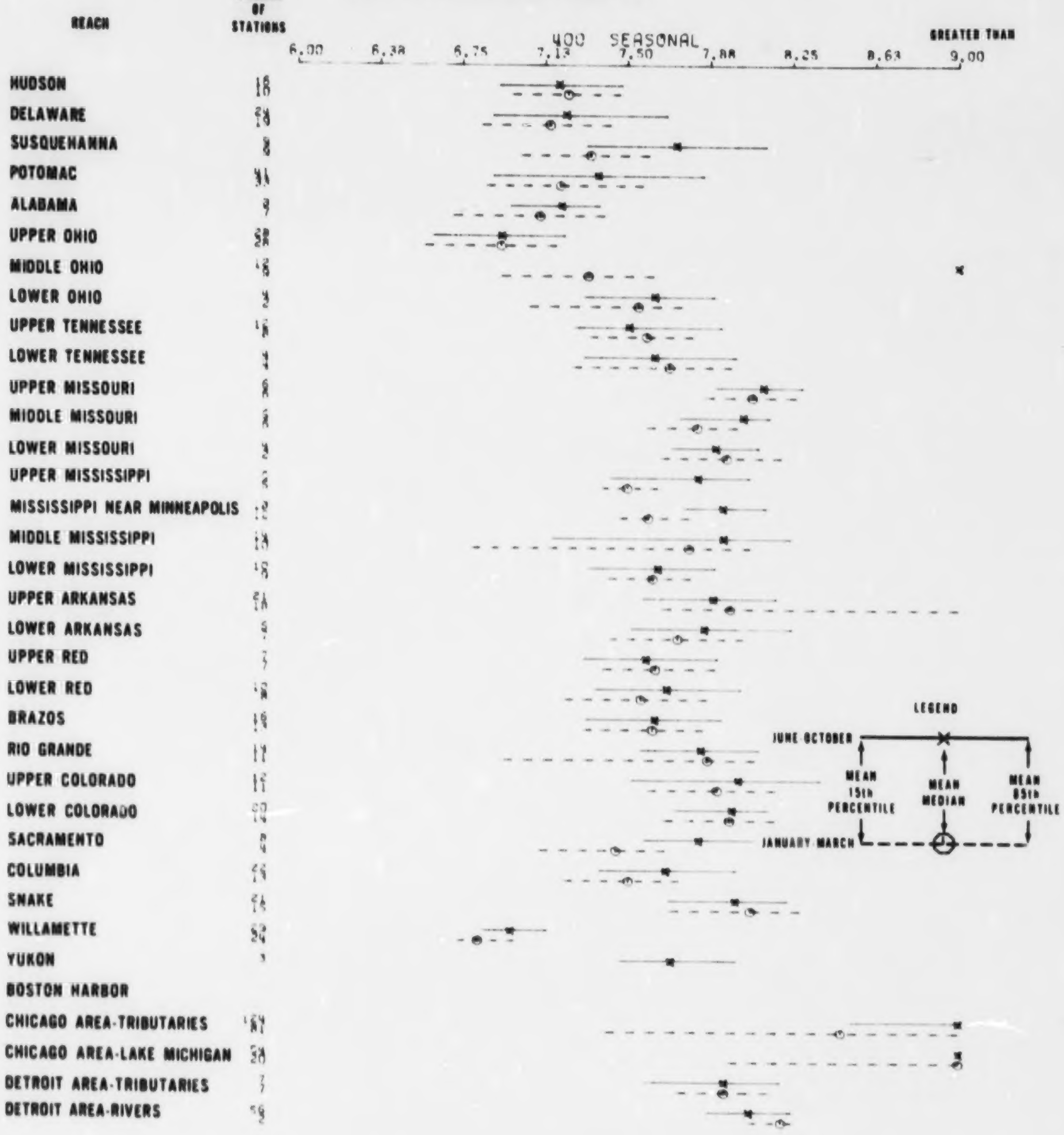


Figure II-14 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

pH-STANDARD UNITS

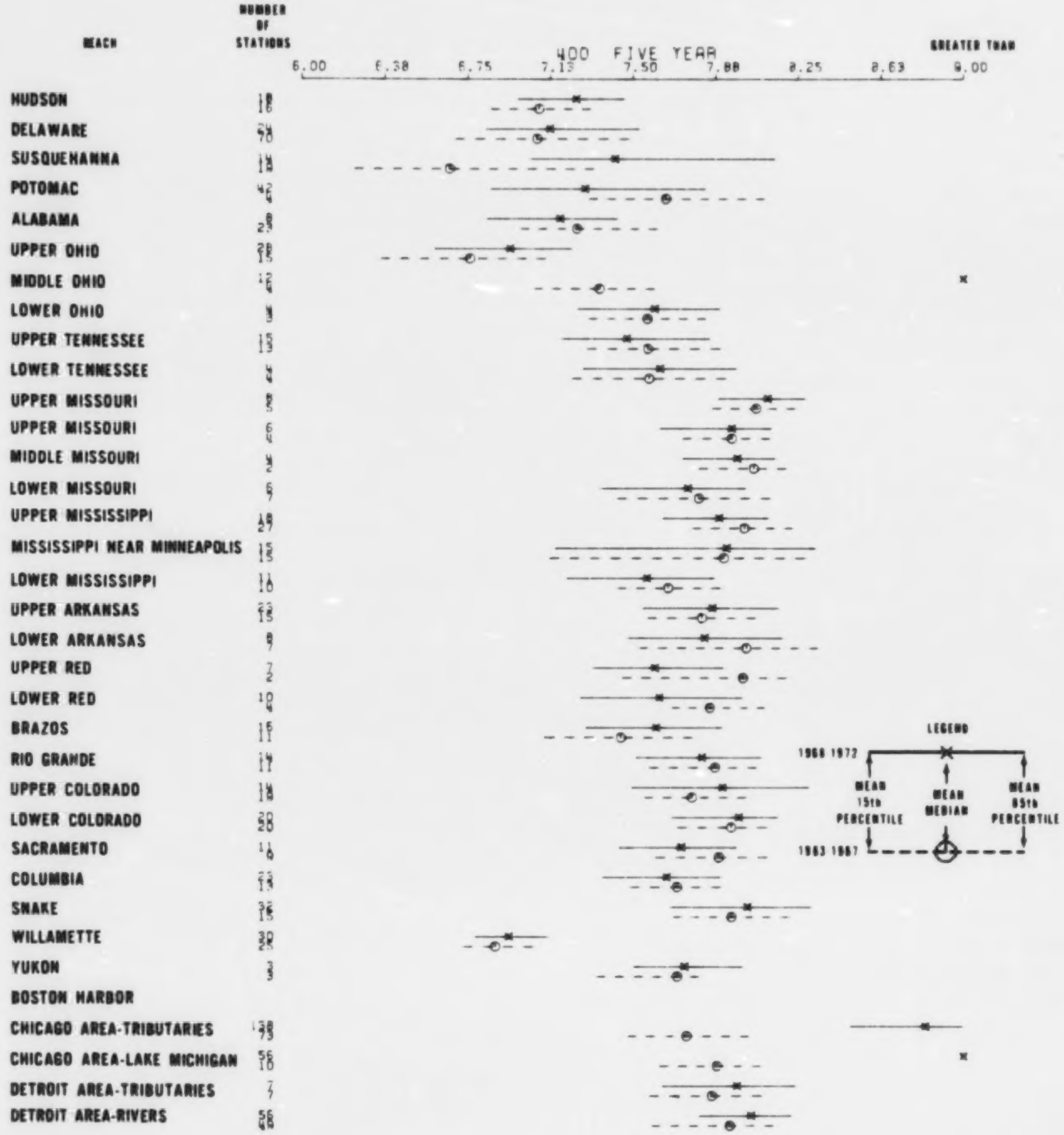


Figure II-15 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL ALKALINITY-mg/ℓ as $CaCO_3$

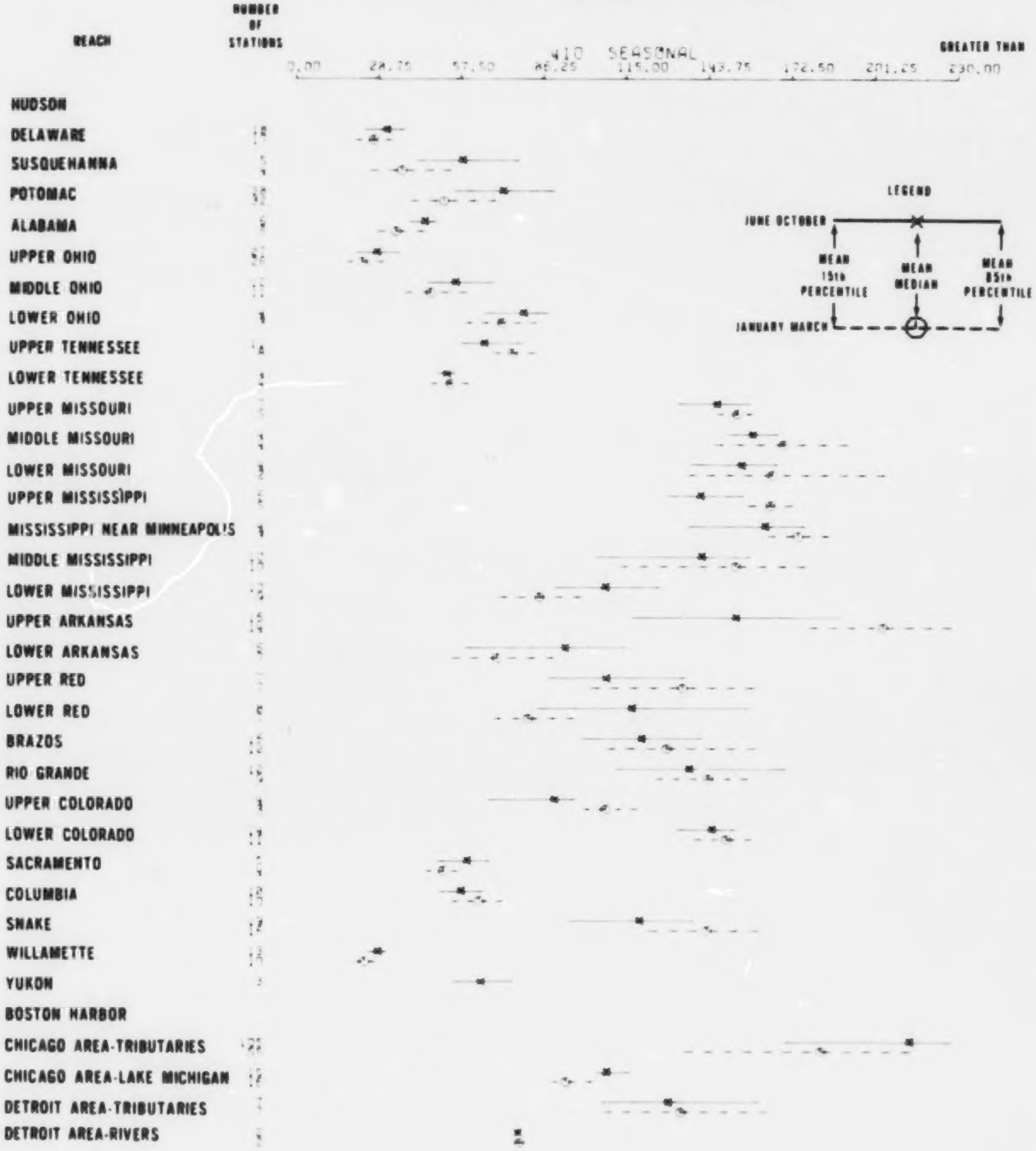


Figure II-16 MEAN PERCENTILES - TIME TRENDS, 1963 -72

22 MAJOR WATERWAYS

TOTAL ALKALINITY-mg/ℓ as C_aCO_3

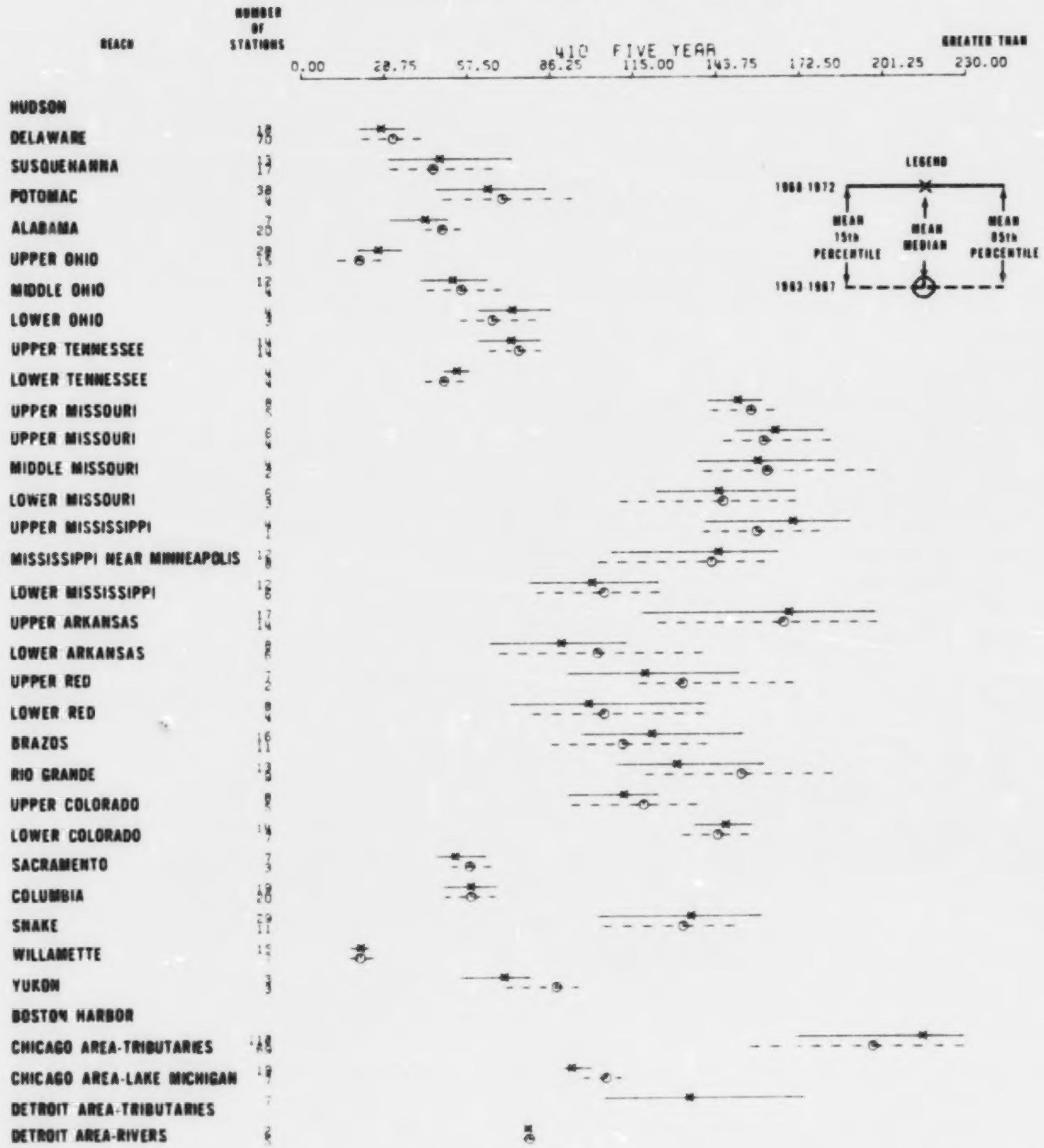


Figure II-17 MEAN PERCENTILES BY SEASON, 1968-72
22 MAJOR WATERWAYS
TOTAL FILTRABLE RESIDUE (105° c)-mg/ℓ (× 10)

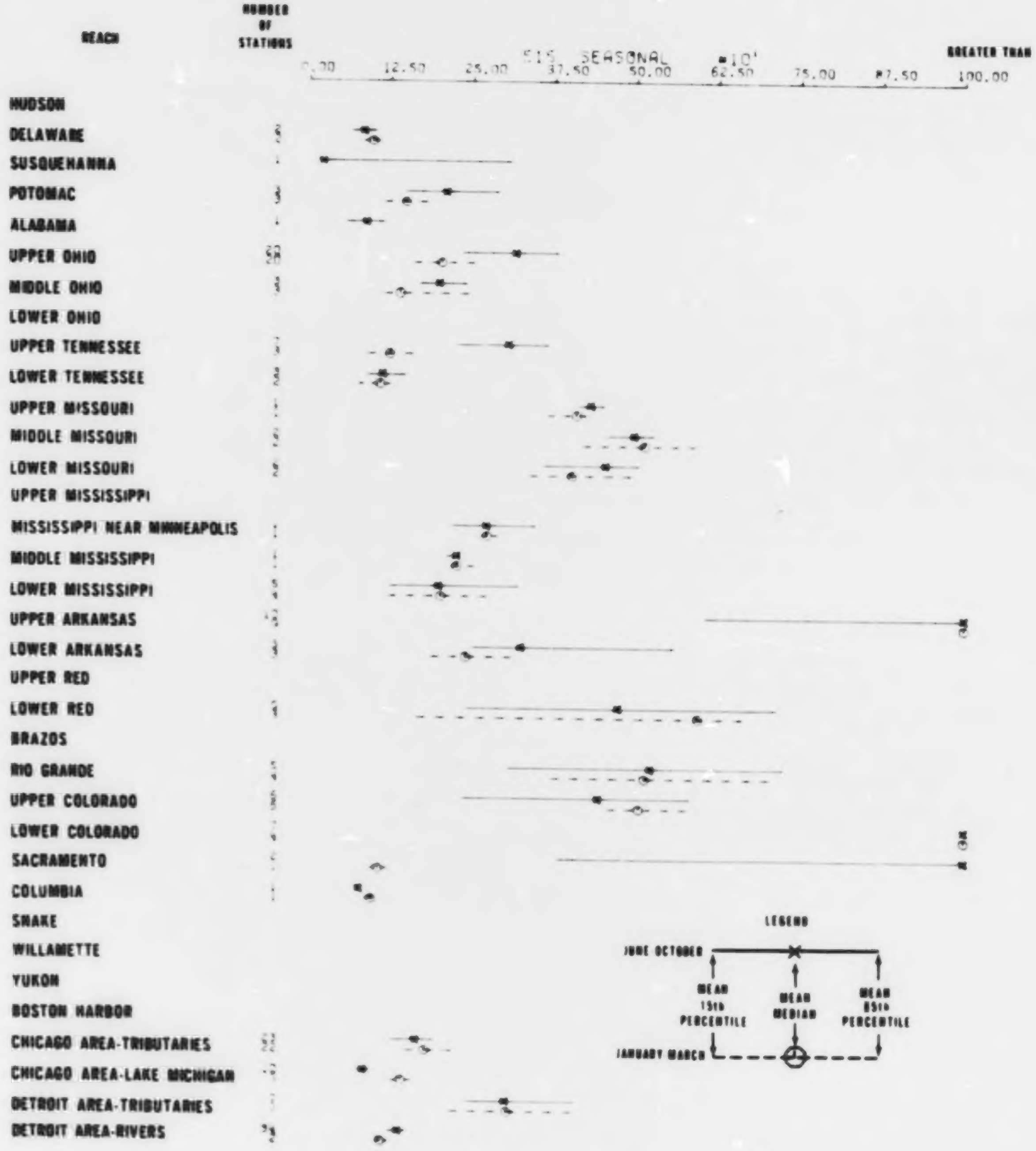


Figure II-18 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL FILTRABLE RESIDUE (105°C)-mg/ℓ (× 10)

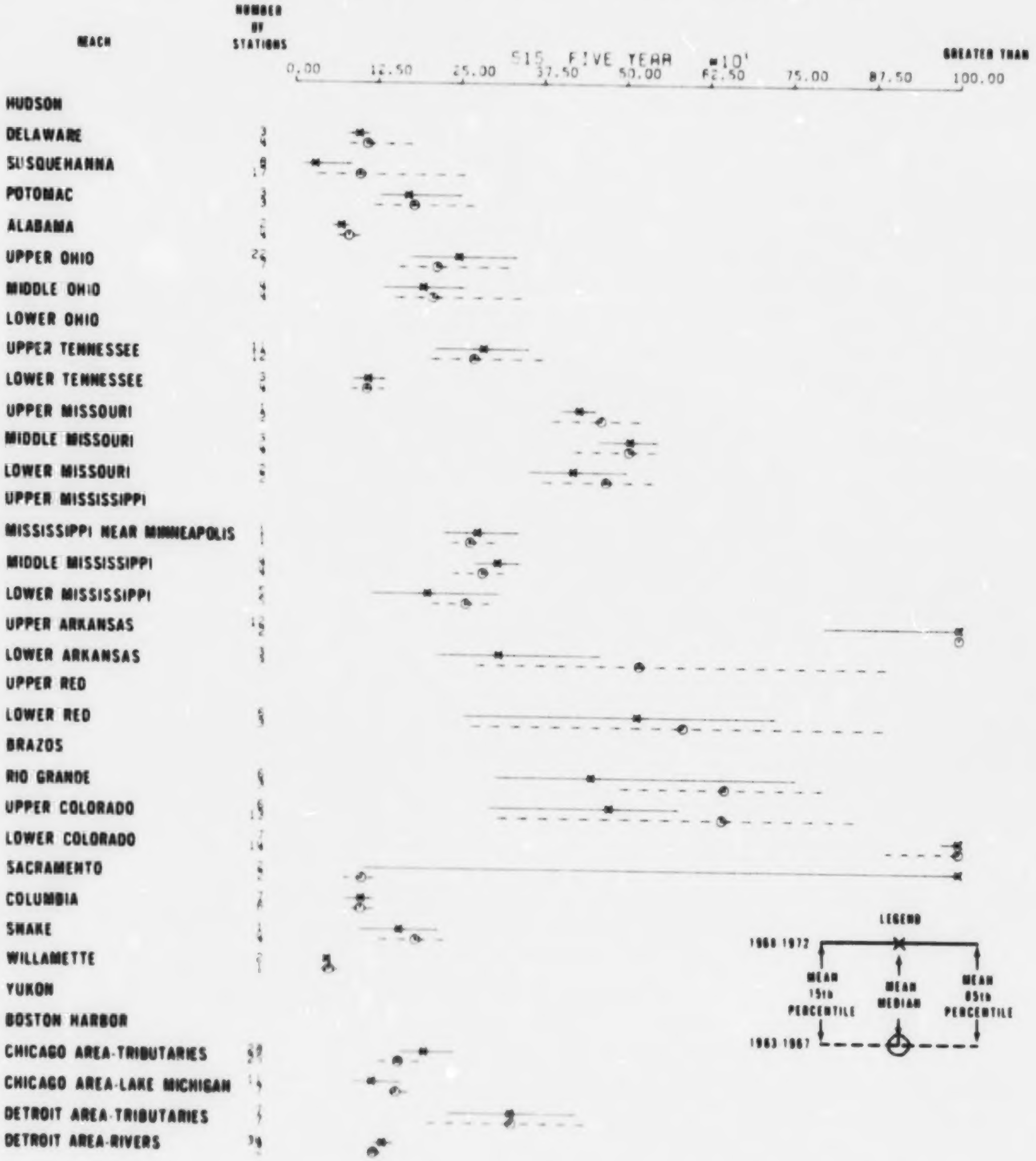


Figure II-19 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL NONFILTRABLE RESIDUE-mg/ℓ

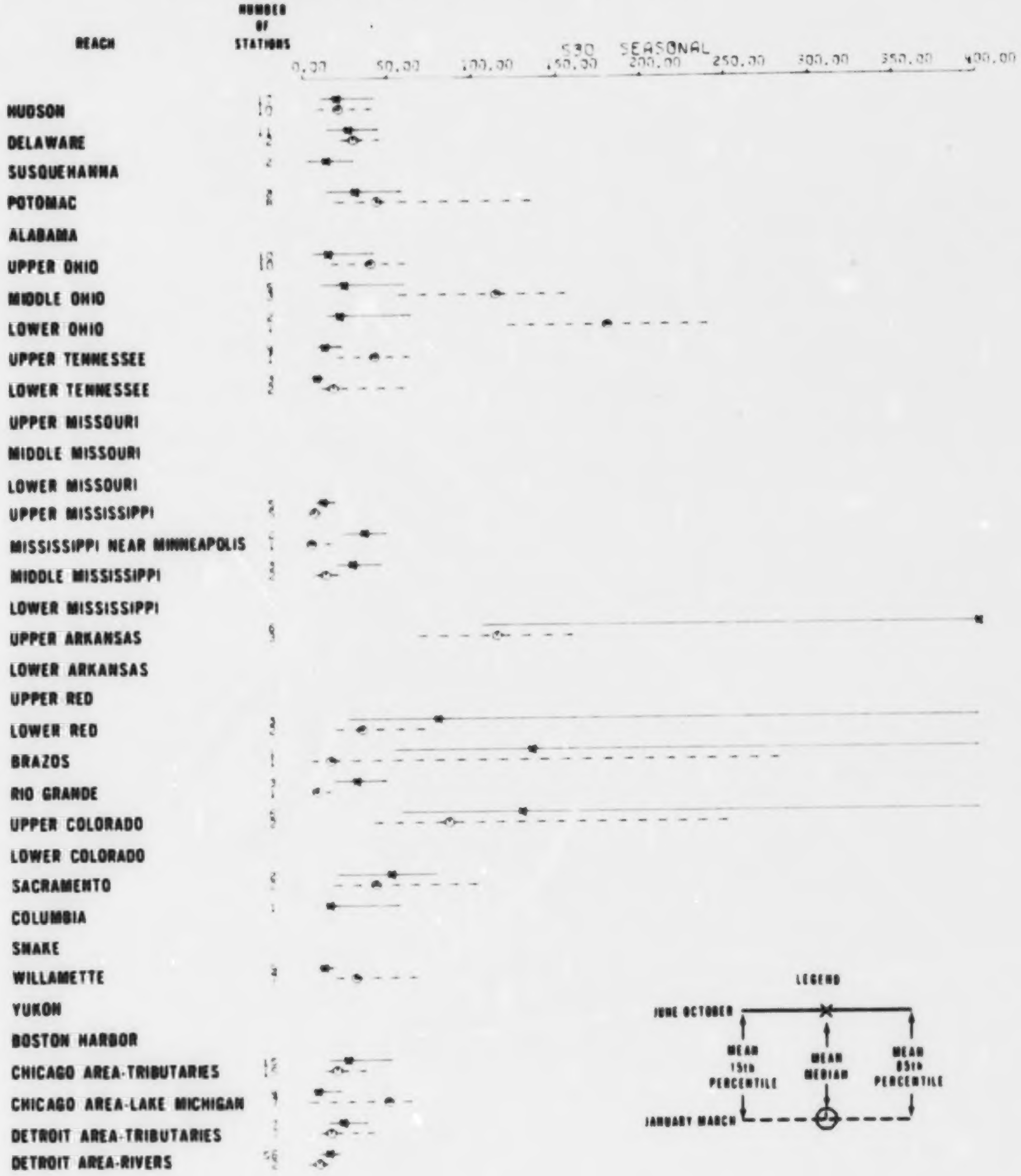


Figure II-20 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL NONFILTRABLE RESIDUE-mg/ℓ

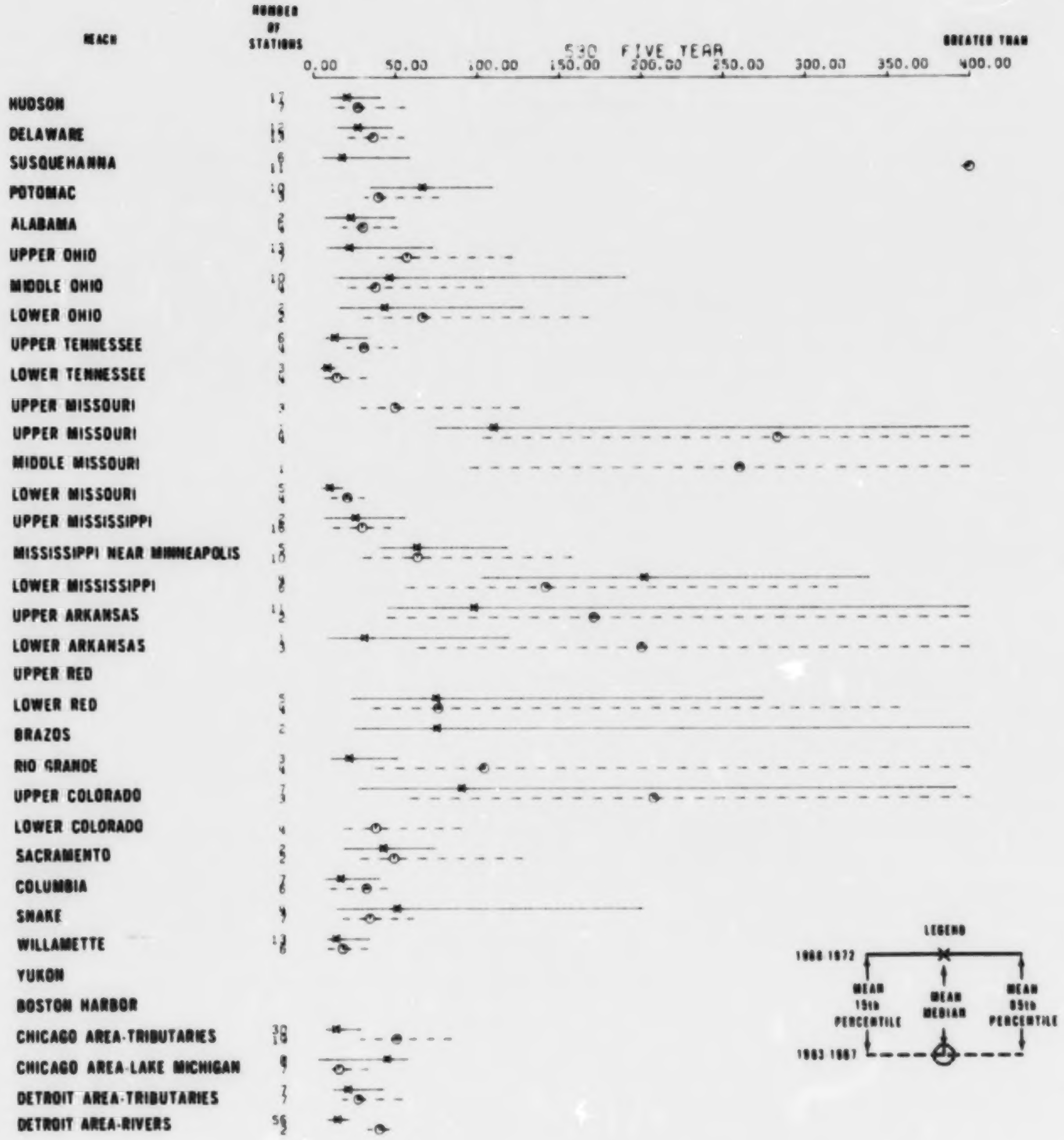


Figure II-21 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL ORGANIC NITROGEN-mg/ℓ as N

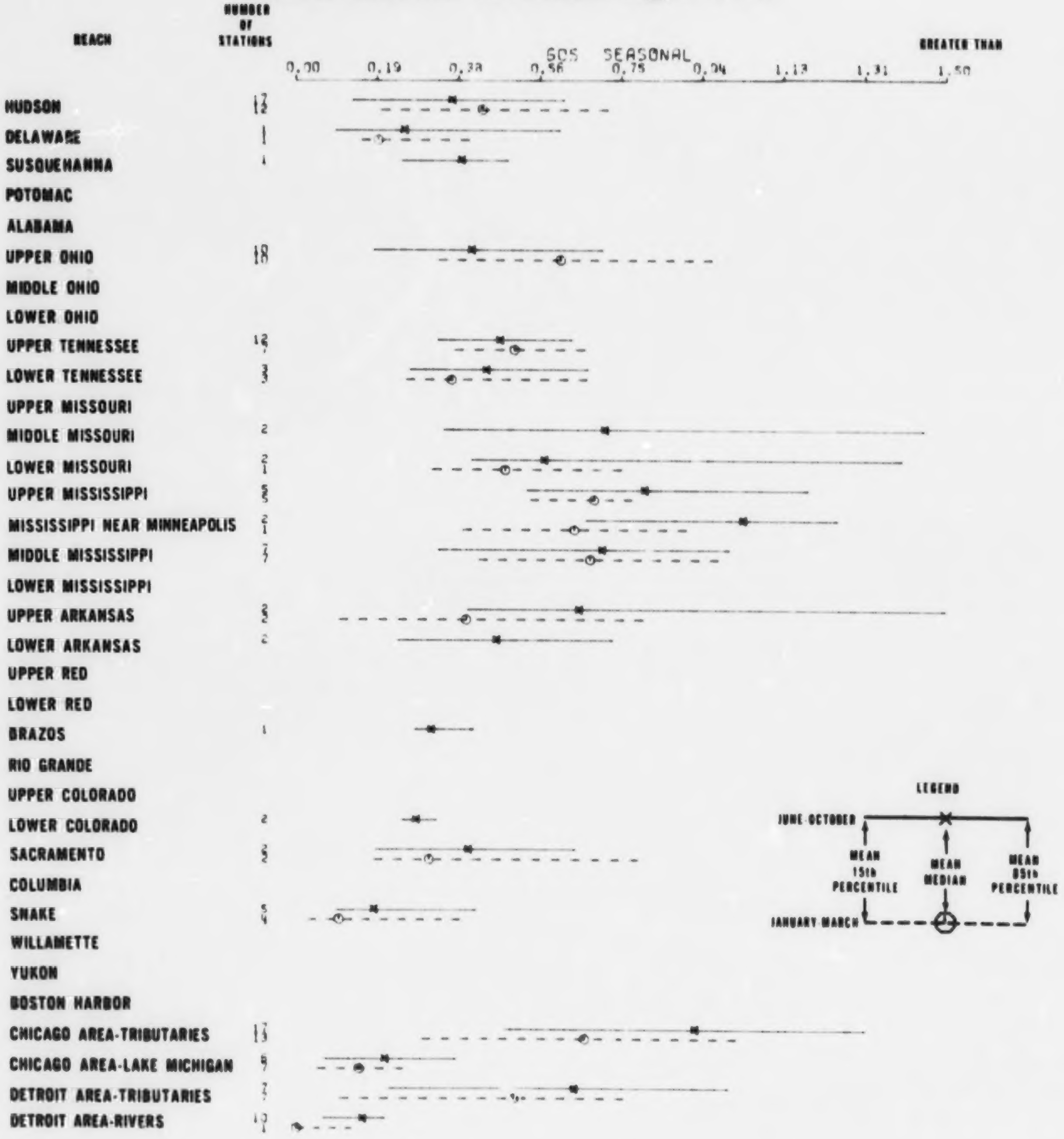


Figure II-22 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL ORGANIC NITROGEN-mg/ℓ as N

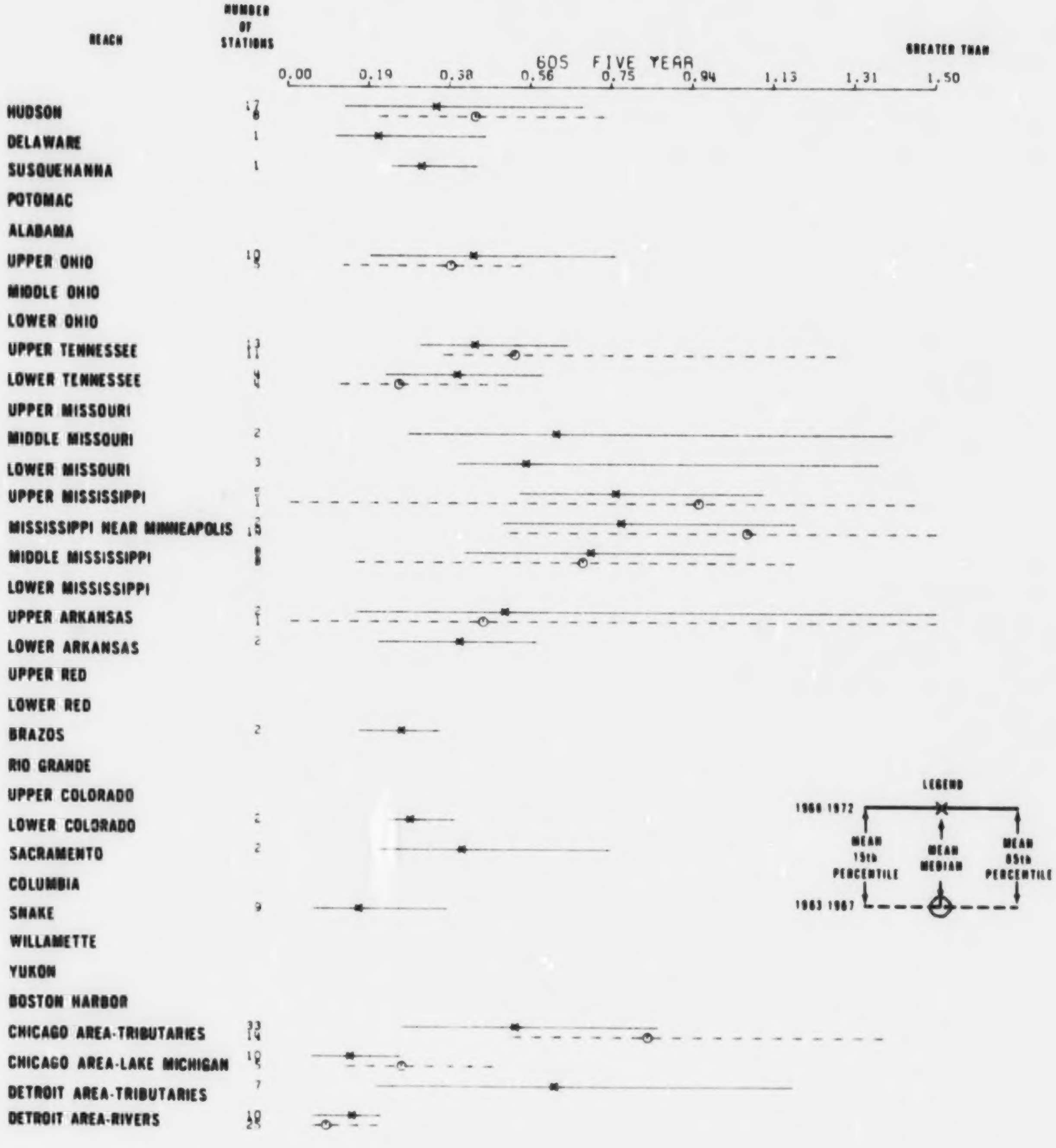


Figure II-23 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL AMMONIA-mg/ℓ as N

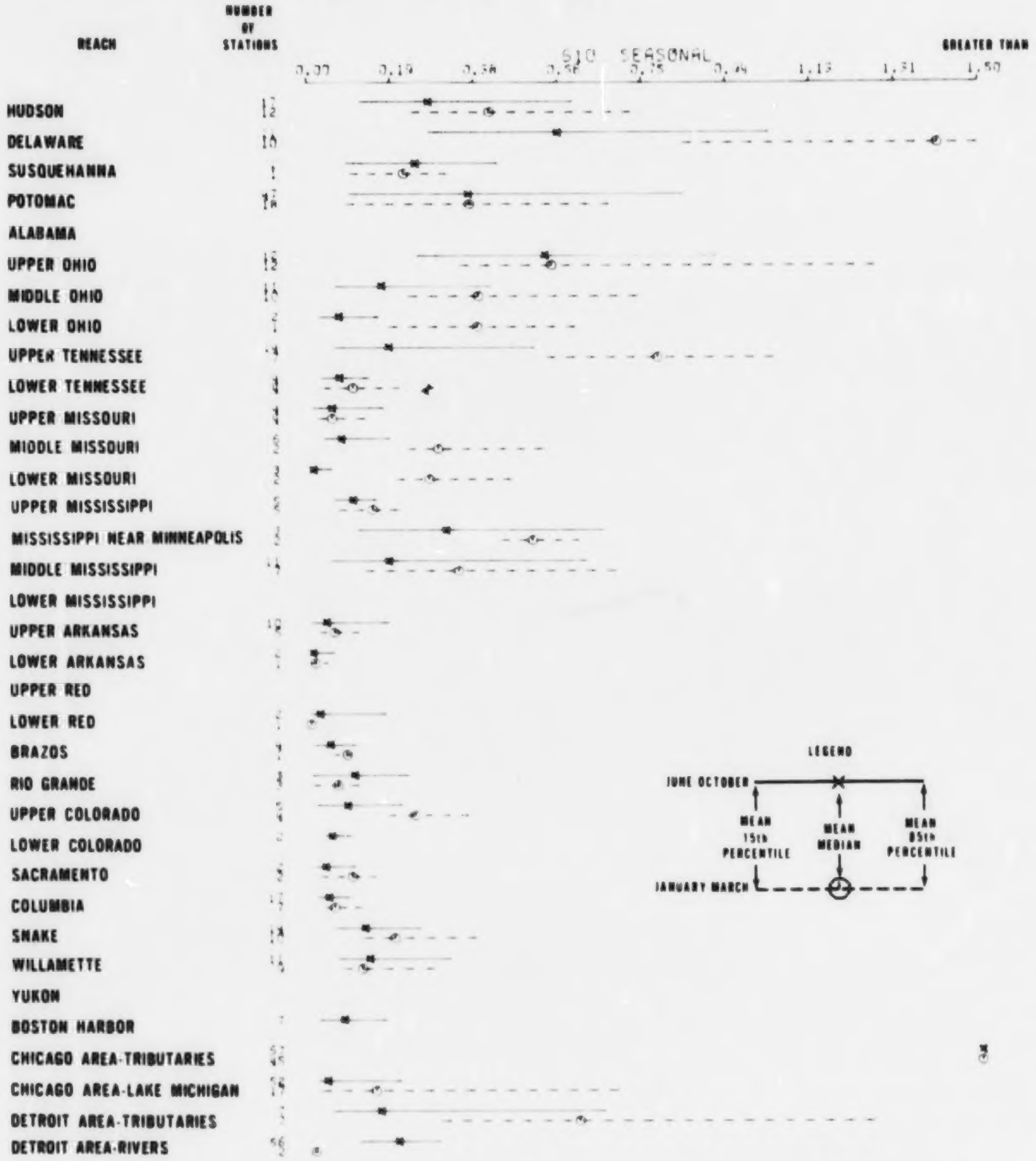


Figure II-24 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL AMMONIA-mg/ℓ as N

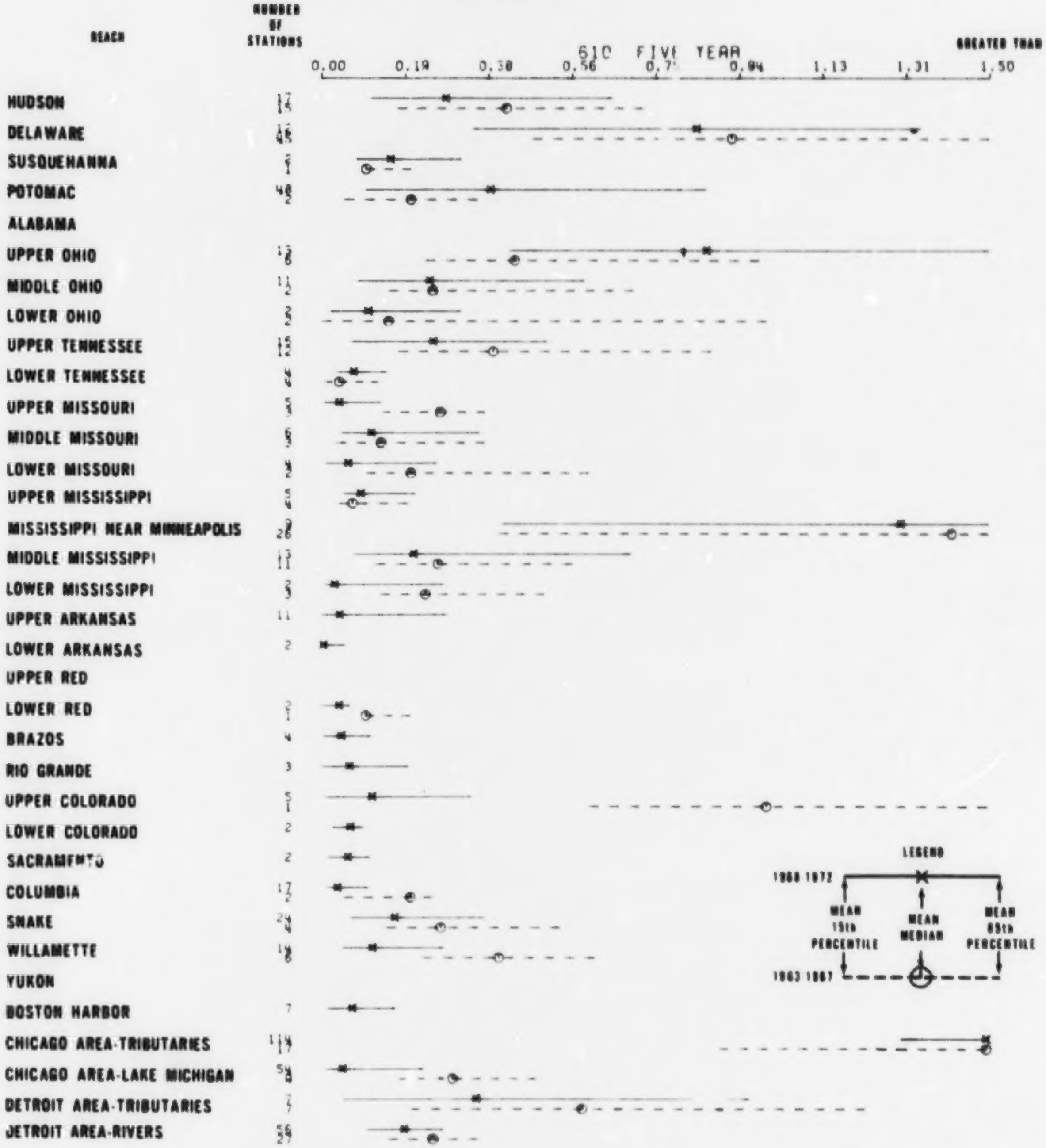


Figure II-25 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL NITRITE PLUS NITRATE-mg/ℓ as N

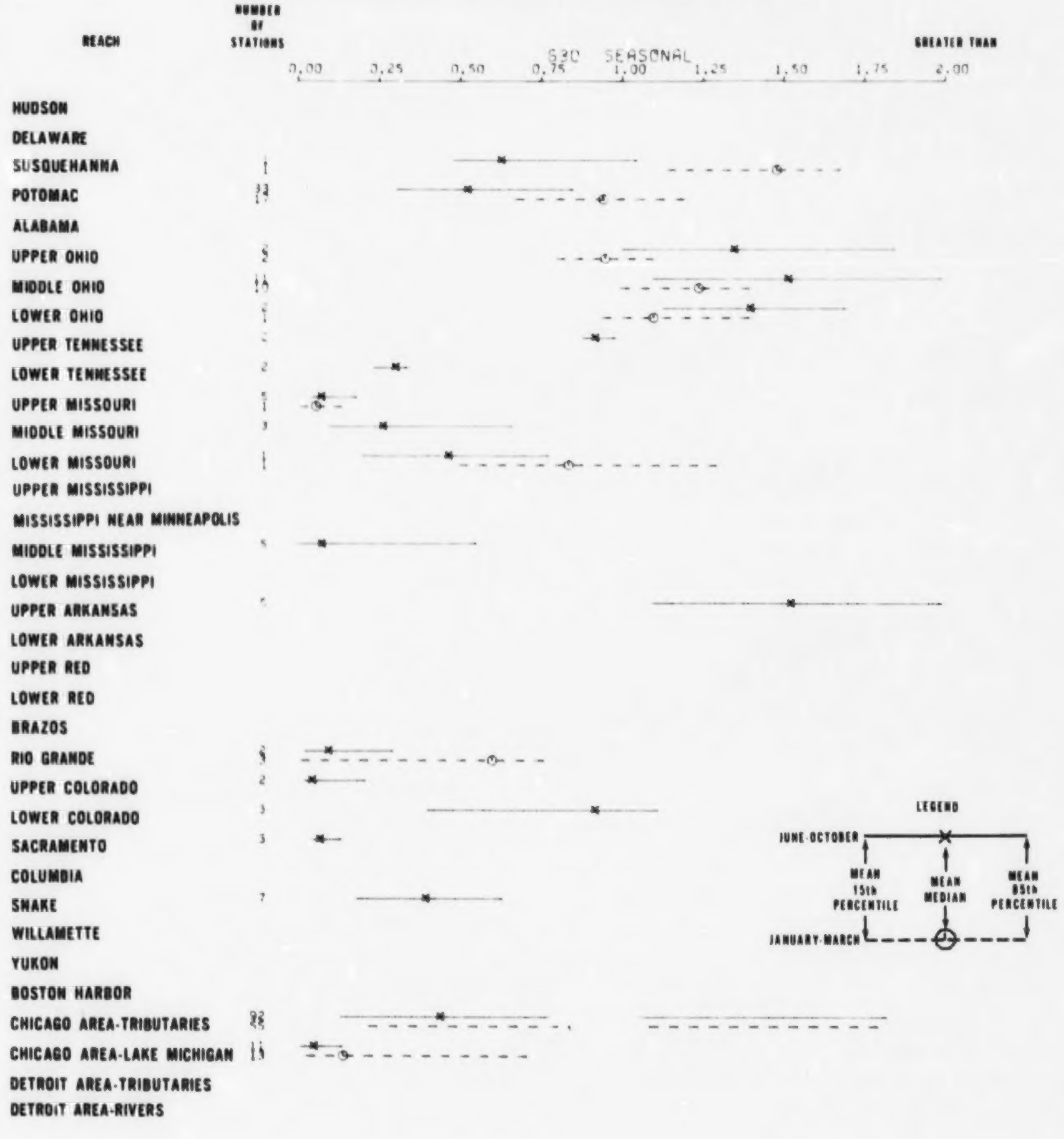


Figure II-26 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL NITRITE PLUS NITRATE-mg/ℓ as N

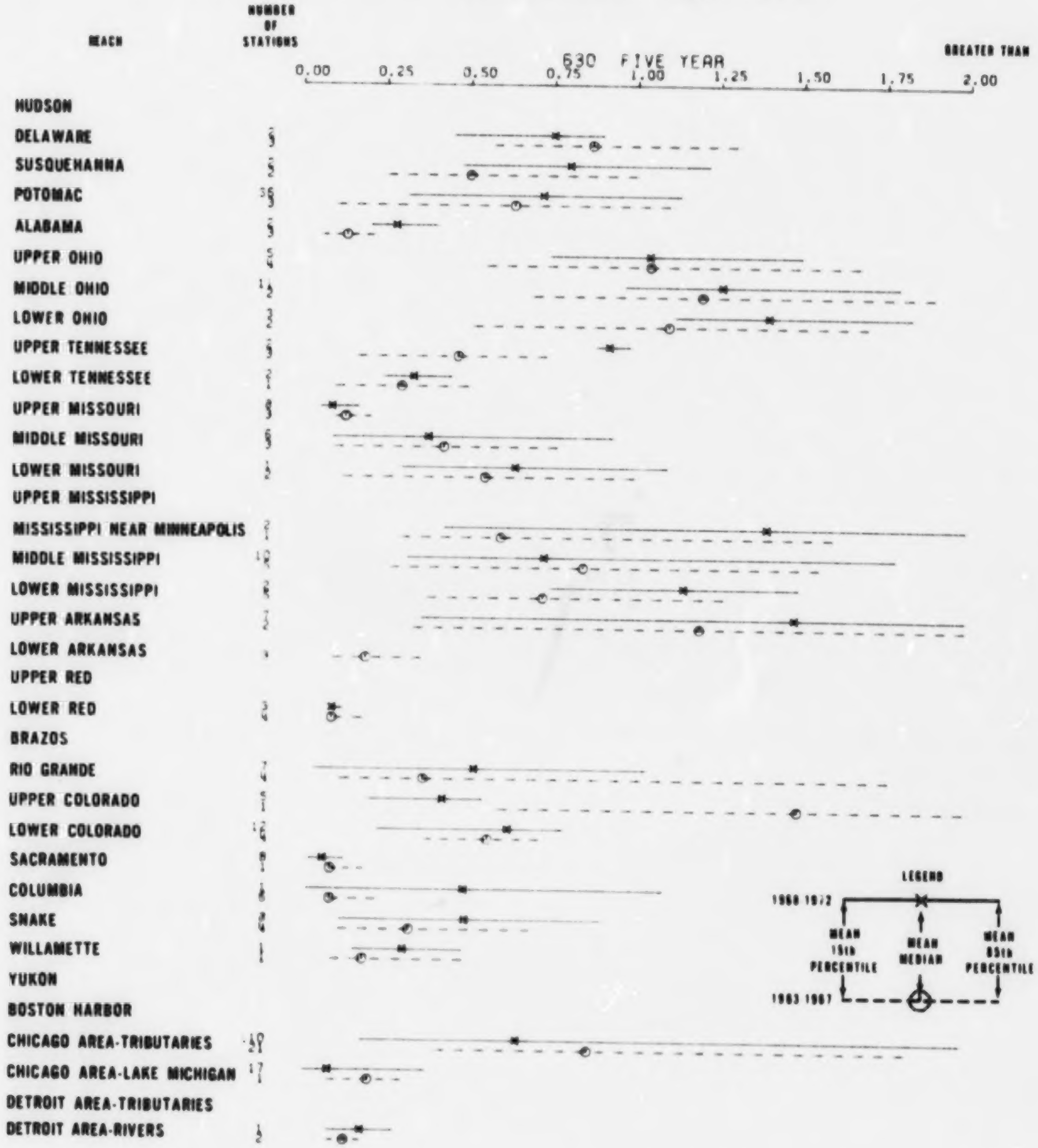


Figure II-27 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL SOLUBLE PHOSPHATE-mg/ℓ as PO4

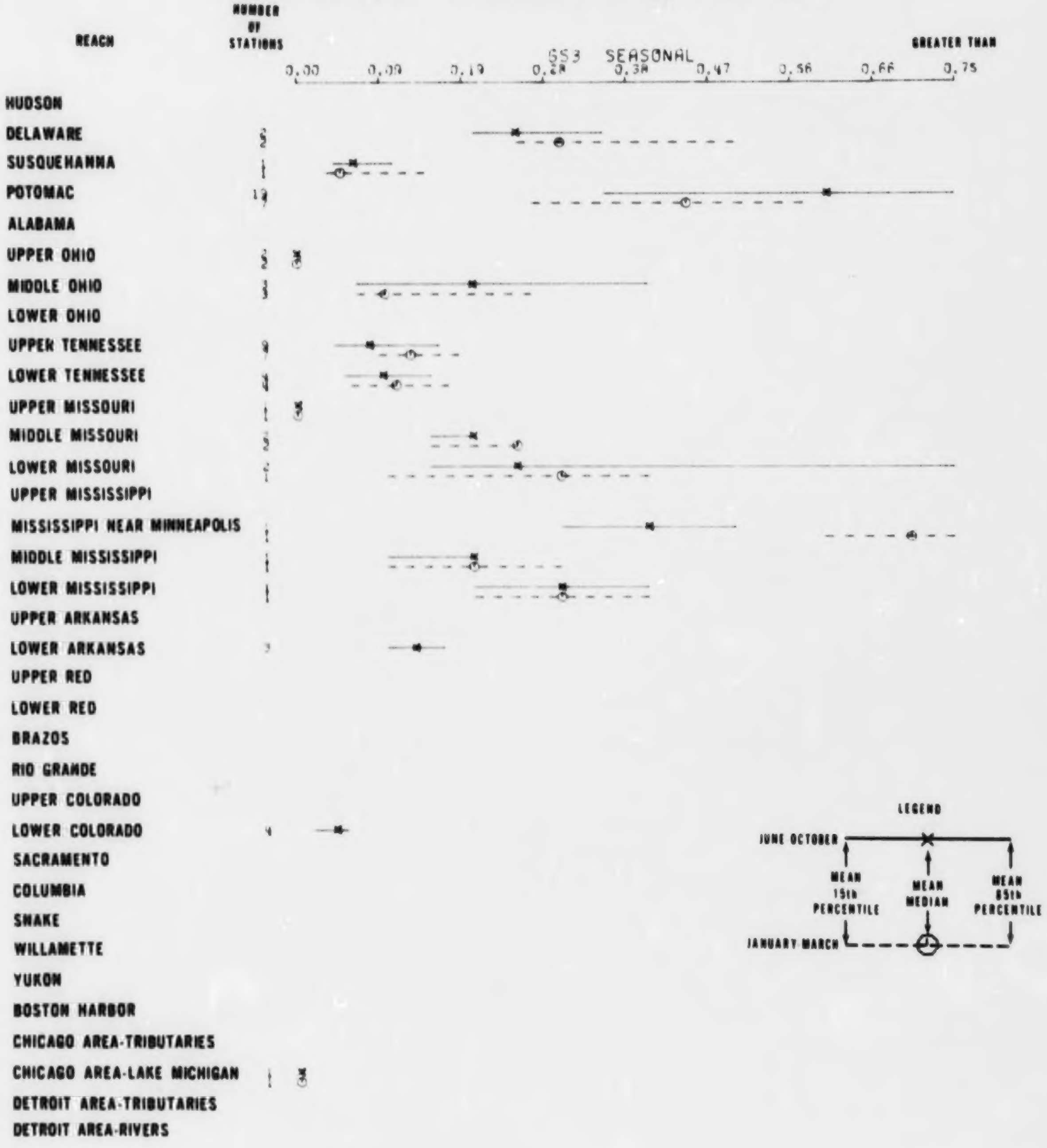


Figure II-28 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL SOLUBLE PHOSPHATE-mg/ℓ as PO_4

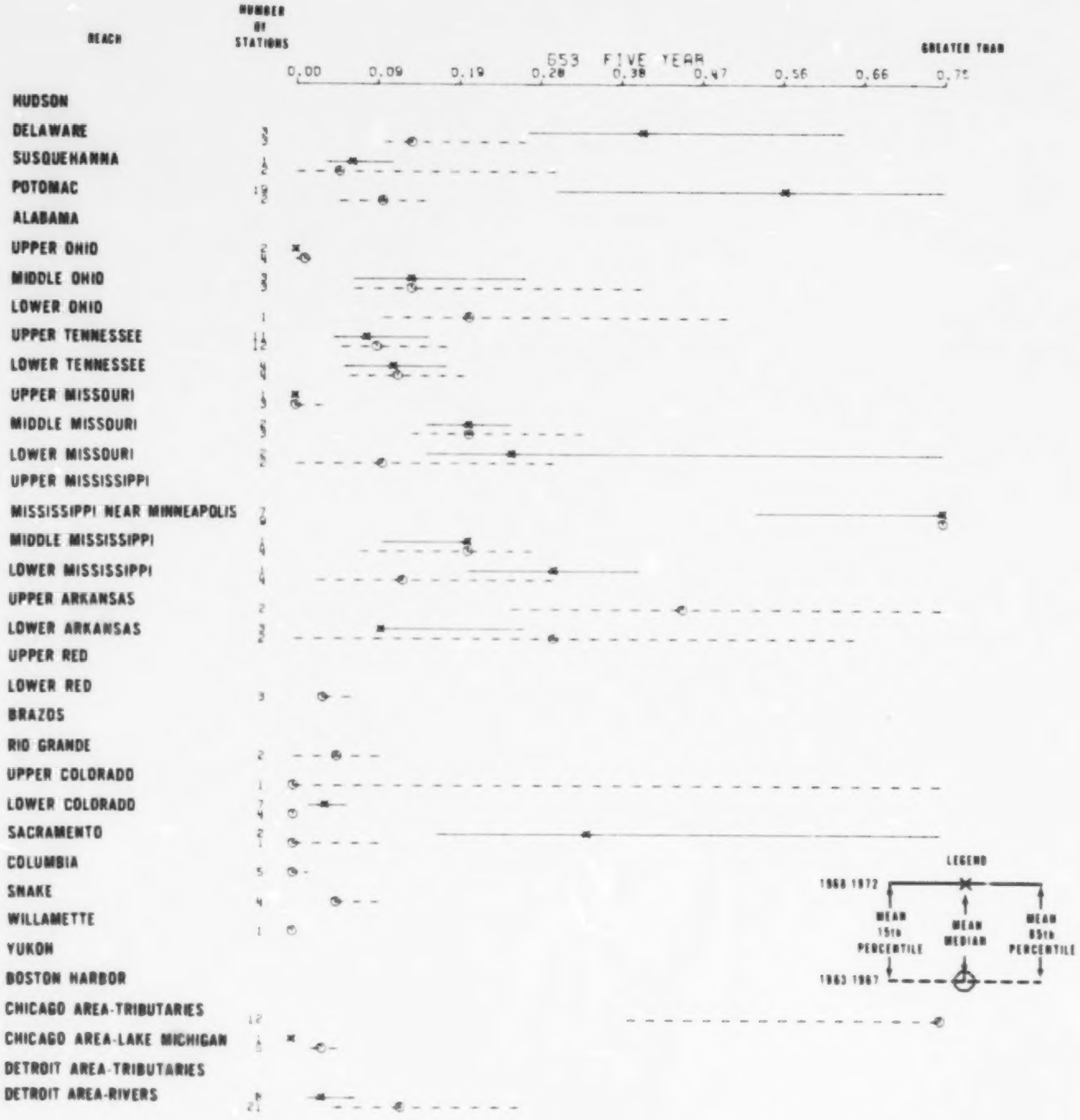


Figure II-29 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL PHOSPHATE-mg/ℓ as P

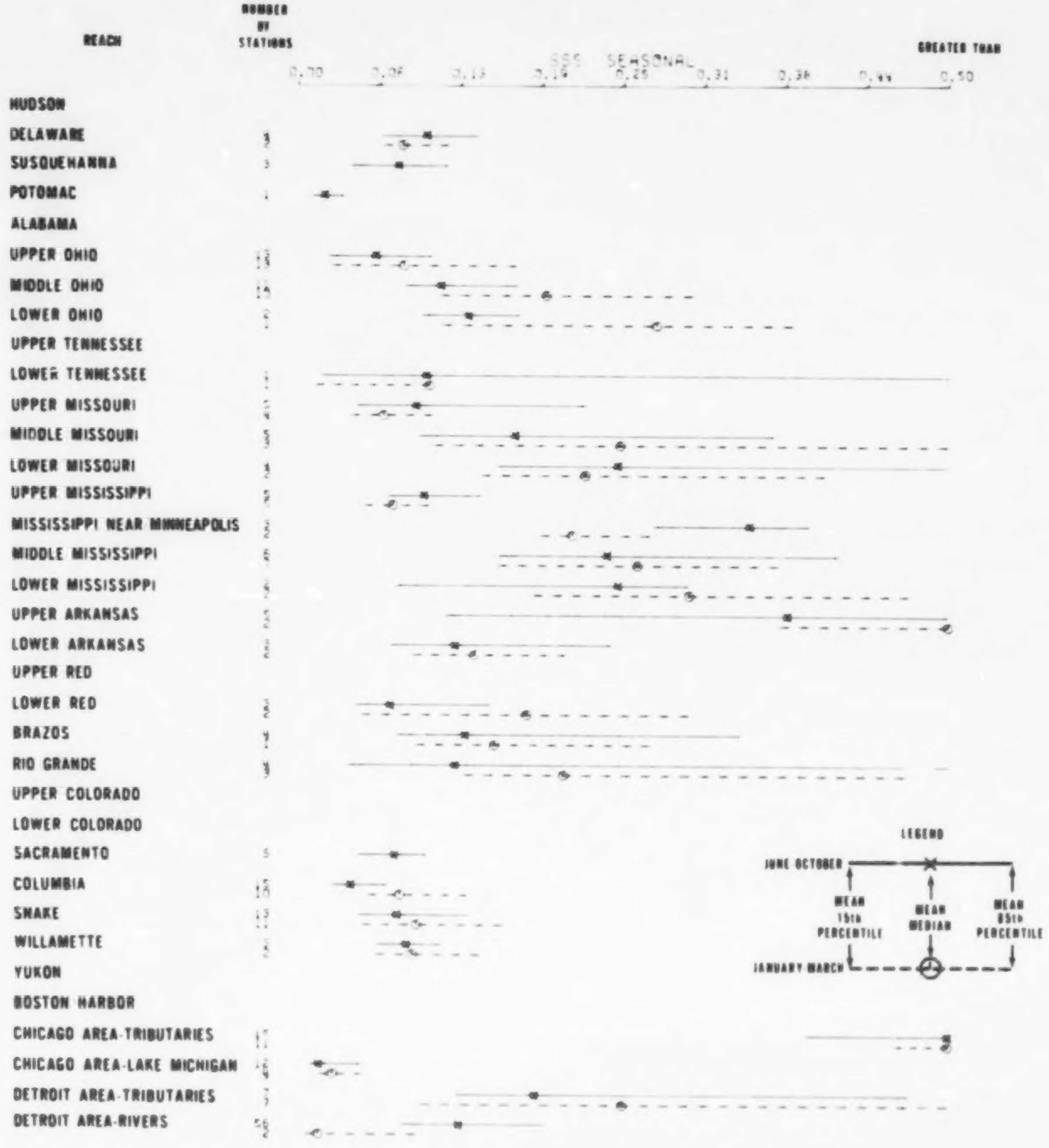


Figure II-30 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL PHOSPHATE-mg/ℓ as P

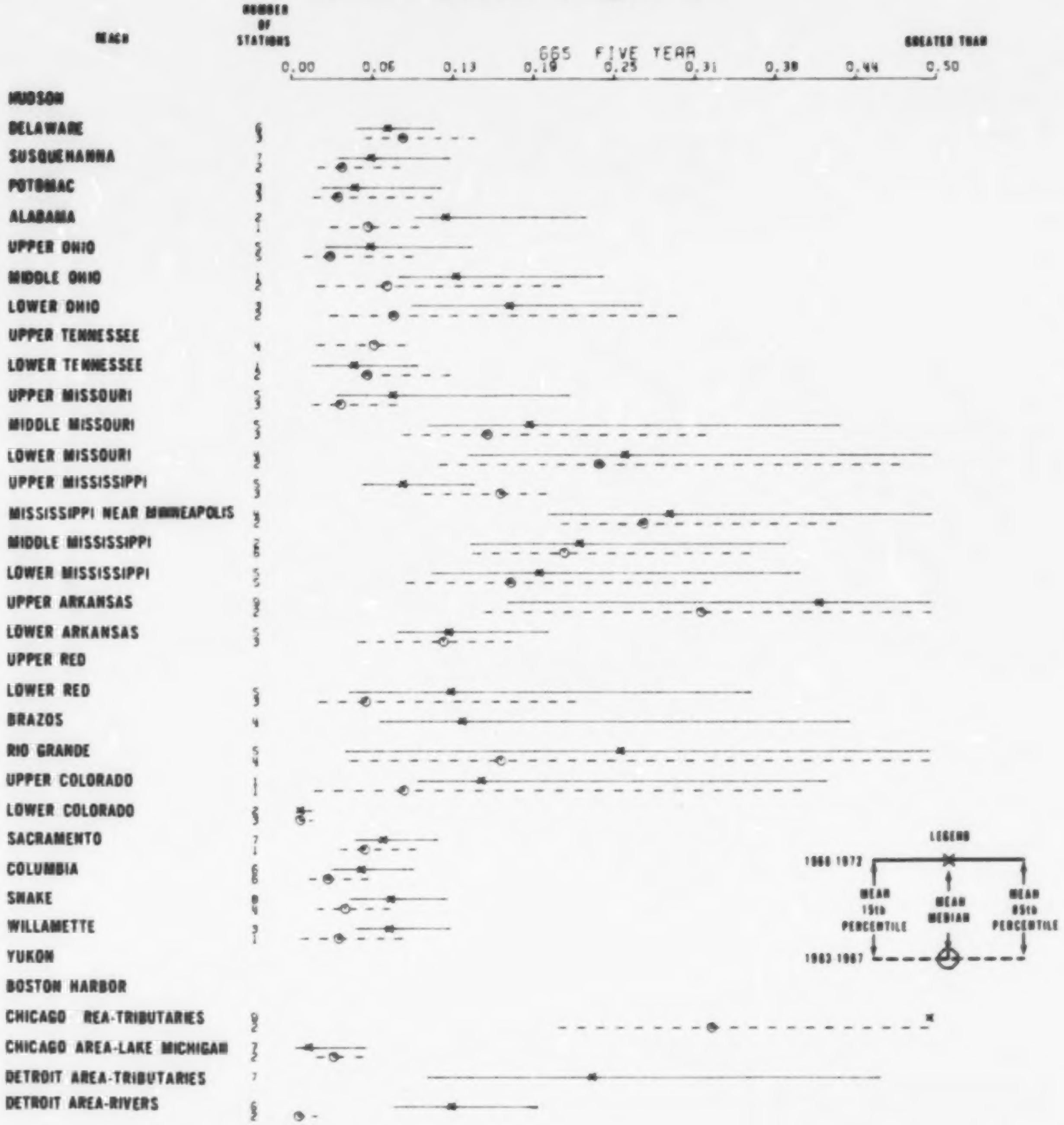


Figure II-31 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

TOTAL HARDNESS-mg/ℓ as $CaCO_3$

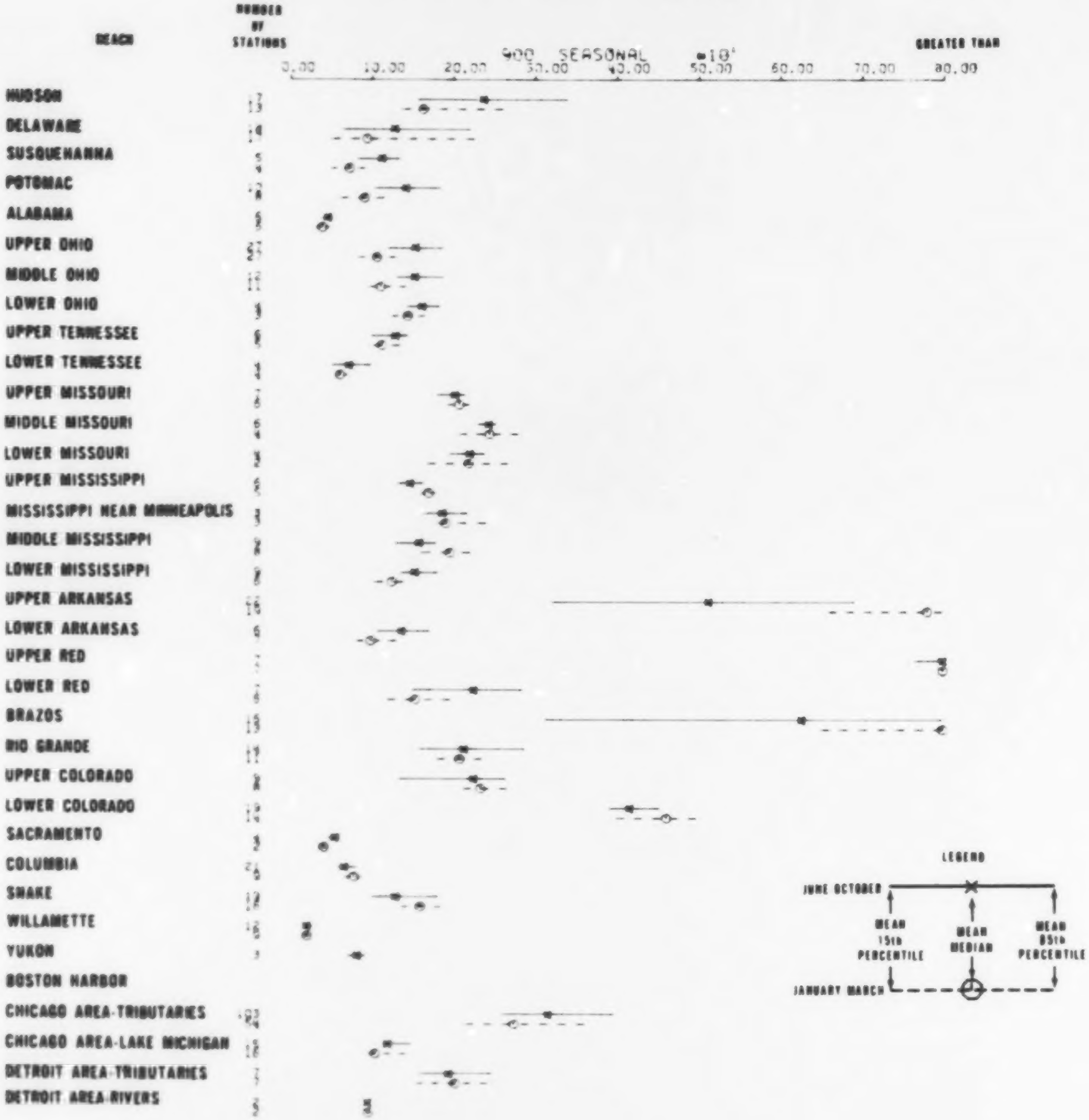


Figure II-32 MEAN PERCENTILES - TIME TRENDS, 1963-72

22 MAJOR WATERWAYS

TOTAL HARDNESS-mg/ℓ as C_aCO_3 (× 10)

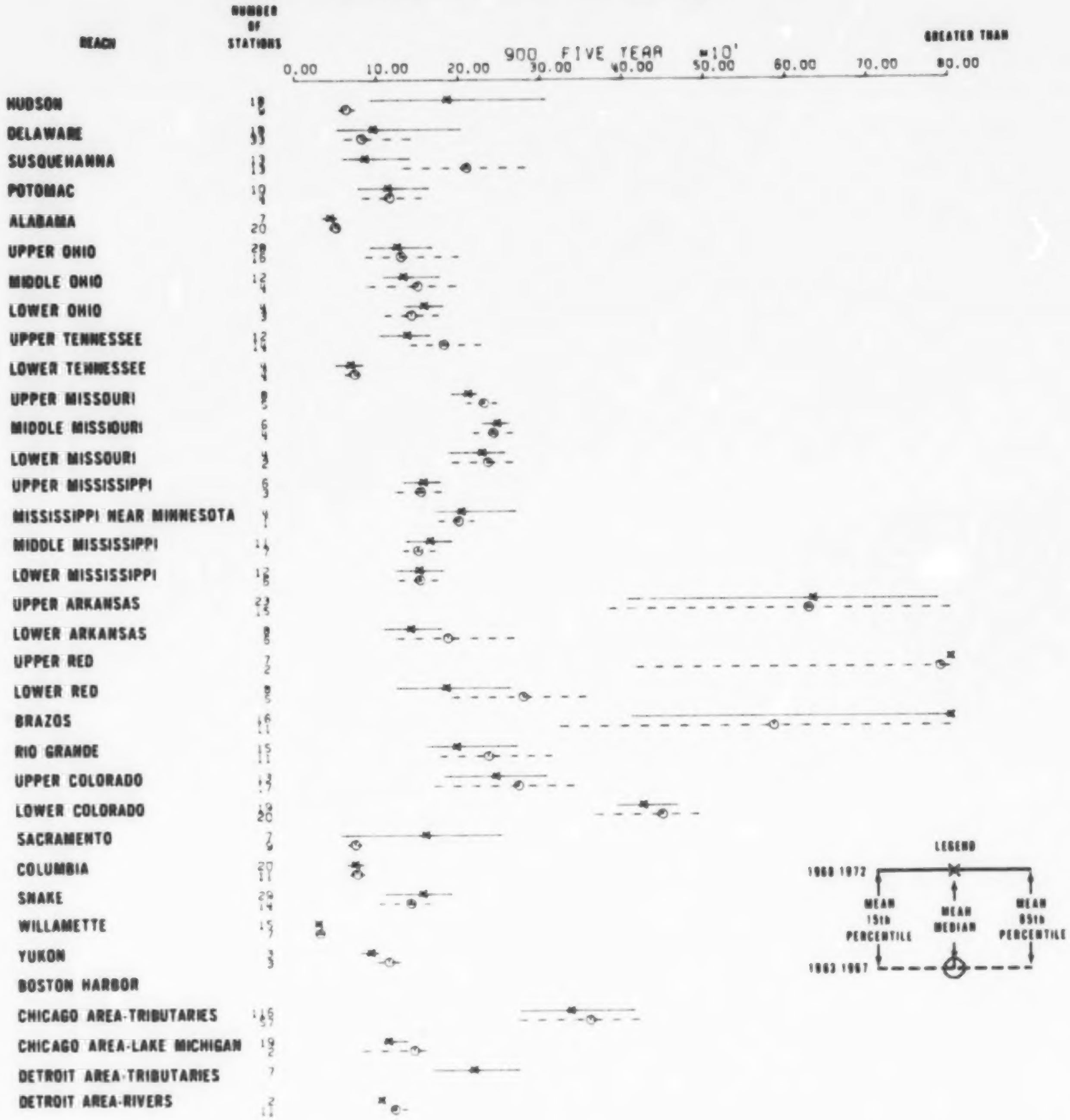
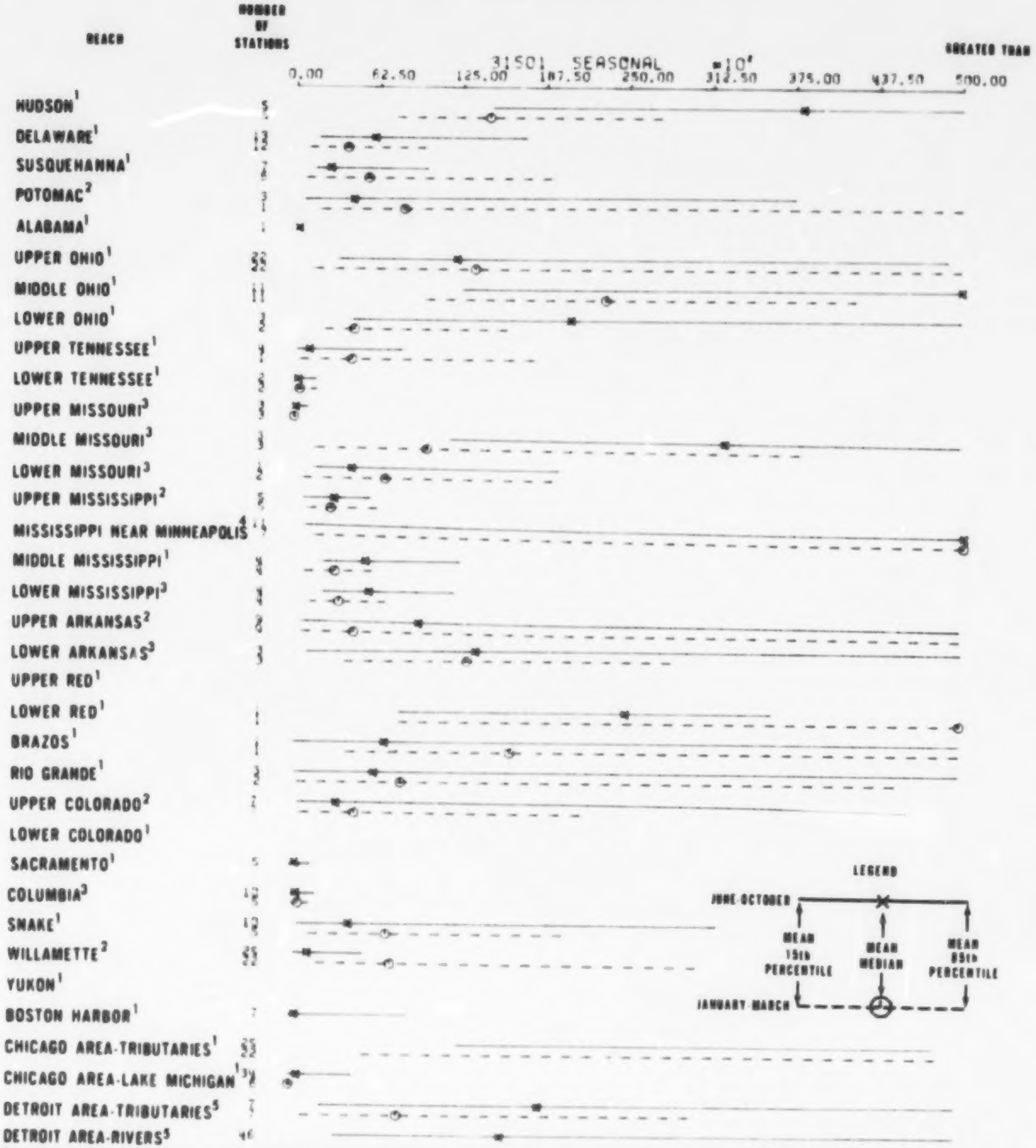
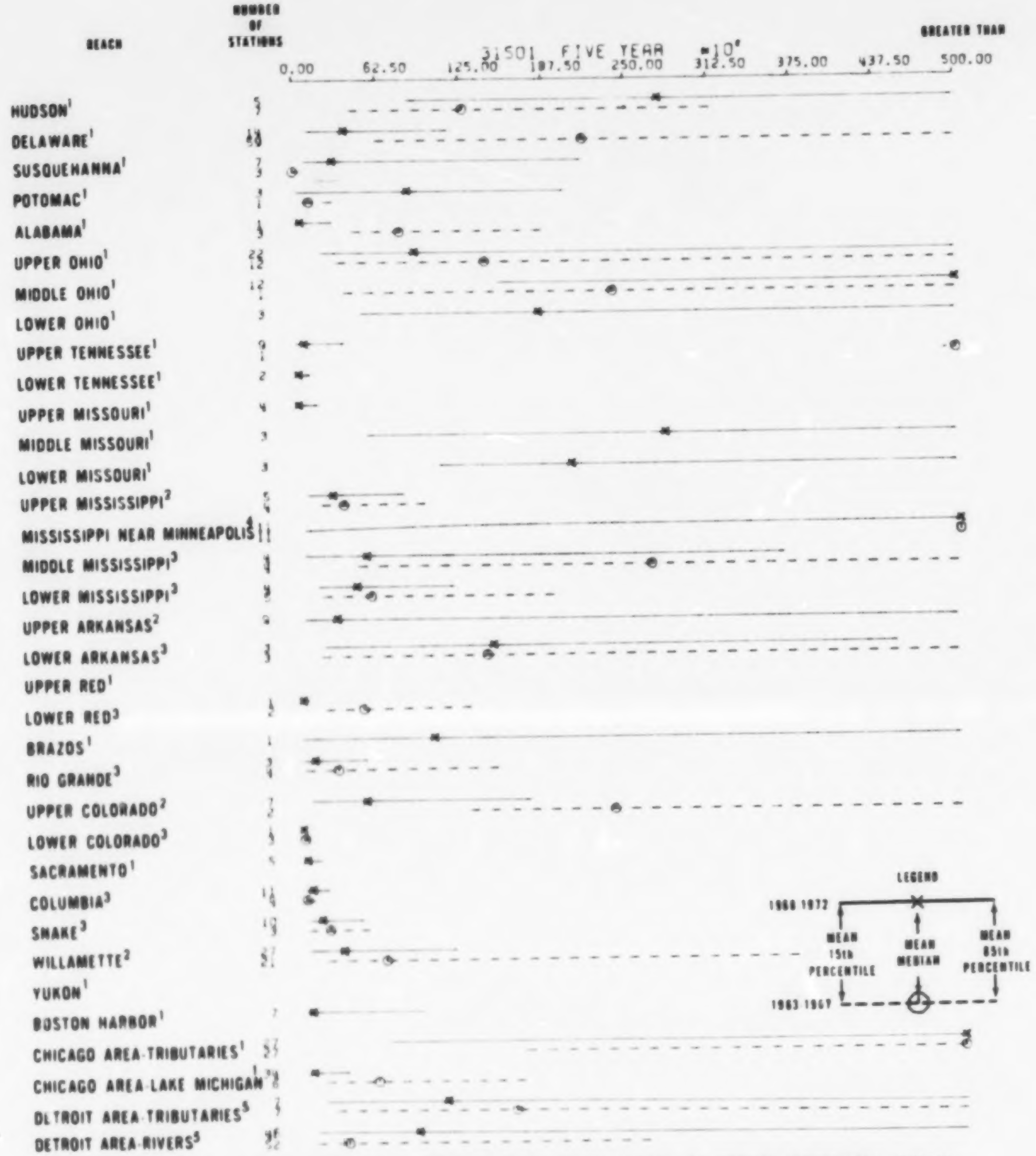


Figure II-33 MEAN PERCENTILES BY SEASON, 1968-72
22 MAJOR WATERWAYS
TOTAL COLIFORMS PER 100mℓ(×100)



1. MEMBRANE FILTER METHOD, IMMEDIATE ANALYSIS, M-ENDO MEDIUM, 35°C
2. MOST PROBABLE NUMBER METHOD, CONFIRMED TEST, 35°C
3. MEMBRANE FILTER METHOD, DELAYED ANALYSIS, M-ENDO MEDIUM, 35°C
4. MOST PROBABLE NUMBER METHOD, COMPLETED TEST, 35°C
5. MEMBRANE FILTER METHOD, IMMEDIATE ANALYSIS, LES ENDO AGAR MEDIUM,35°C

Figure II-34 MEAN PERCENTILES - TIME TRENDS, 1963-72
22 MAJOR WATERWAYS
TOTAL COLIFORMS PER 100mℓ (×100)

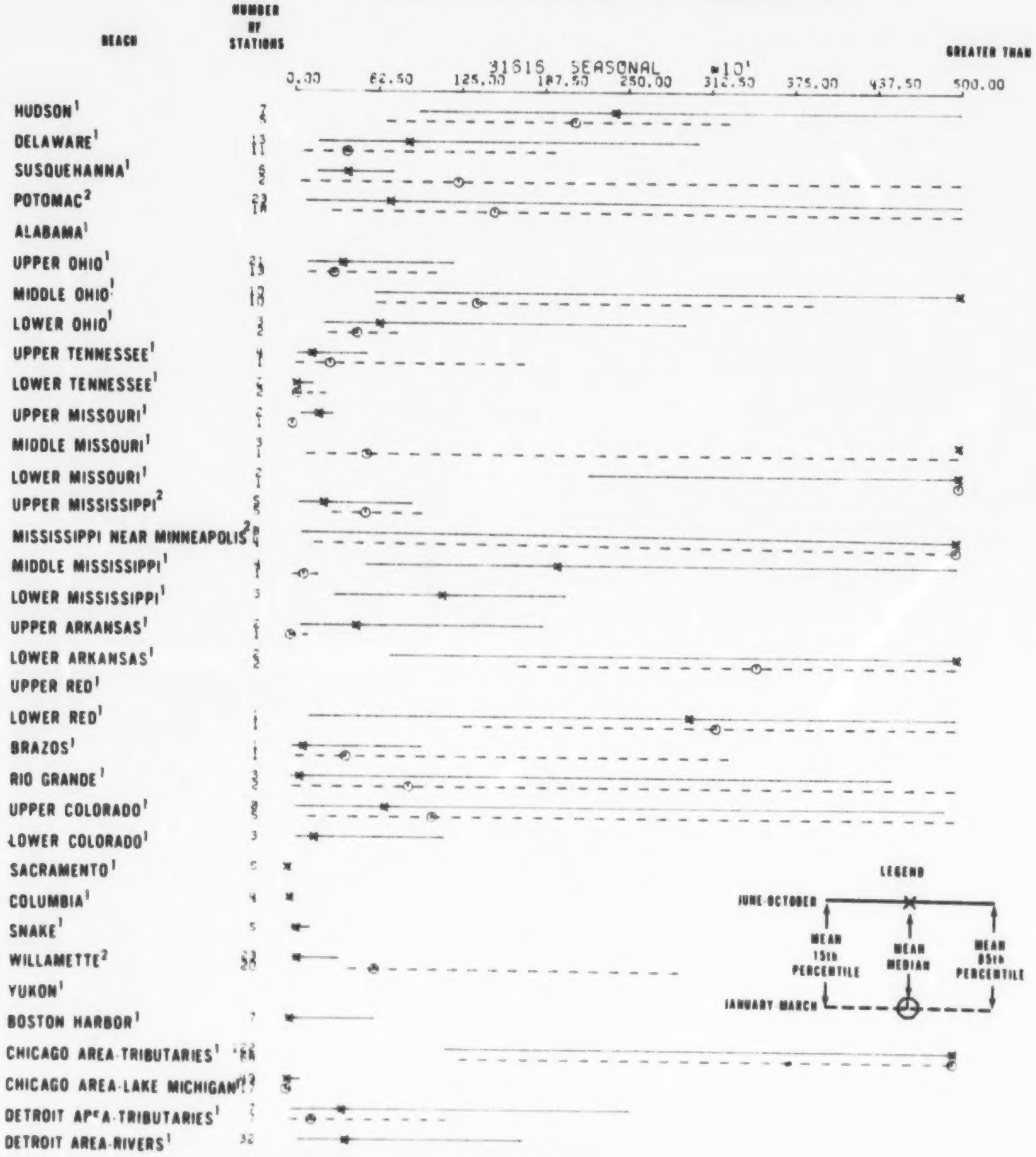


1. MEMBRANE FILTER METHOD, IMMEDIATE ANALYSIS, M-ENDO MEDIUM, 35°C
2. MOST PROBABLE NUMBER METHOD, CONFIRMED TEST, 35°C
3. MEMBRANE FILTER METHOD, DELAYED ANALYSIS, M-ENDO MEDIUM, 35°C
4. MOST PROBABLE NUMBER METHOD, COMPLETED TEST, 35°C
5. MEMBRANE FILTER METHOD, IMMEDIATE ANALYSIS, LES ENDO AGAR MEDIUM, 35°C

Figure II-35 MEAN PERCENTILES BY SEASON, 1968-72

22 MAJOR WATERWAYS

FECAL COLIFORMS PER 100mℓ (×10)

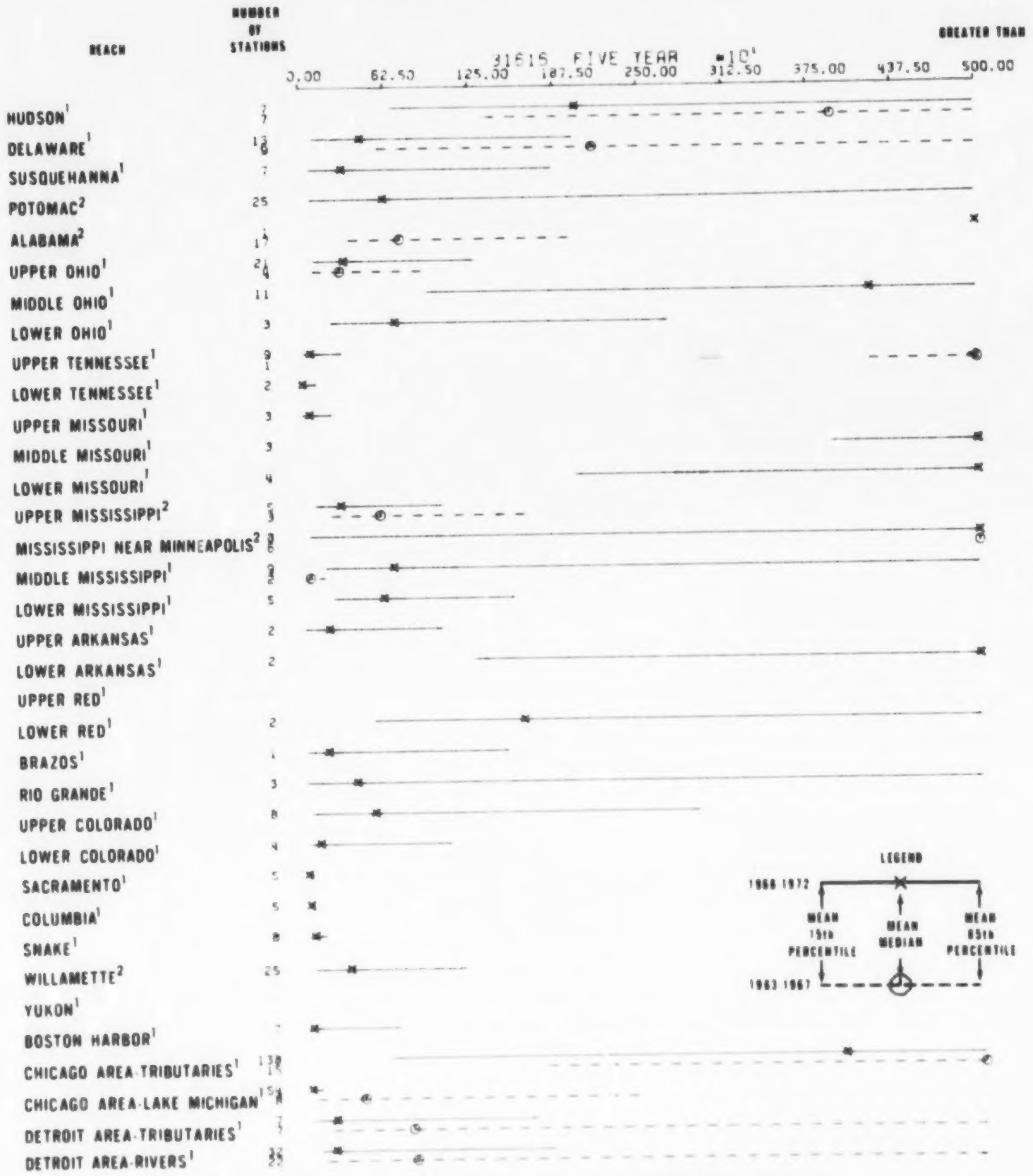


1. MEMBRANE FILTER METHOD, M-FC BROTH, 44.5°C
2. MOST PROBABLE NUMBER METHOD, EC MEDIUM, 44.5°C

Figure II-36 MEAN PERCENTILES - TIME TRENDS, 1968-72

22 MAJOR WATERWAYS

FECAL COLIFORMS PER 100 mℓ (×10)



1. MEMBRANE FILTER METHOD, M-FC BROTH, 44.5°C
2. MOST PROBABLE NUMBER METHOD, EC MEDIUM, 44.5°C

III. MISSISSIPPI RIVER

The most significant types of pollution in the Mississippi River, according to routine water monitoring data for 1963-72, are the presence of undesirable bacteria throughout the river (most noticeably around urban centers) and elevated levels of phenols. Special studies confirmed the presence of phenols, which cause taste and odor problems in drinking water and fish flesh, downstream from cities and industrial complexes. Commercial fishing is now prohibited in several long segments of the Mississippi. The key parameters highlight the pollution problems of the river:

- *Physical Modification.* Levels of BOD_5, ammonia, and nitrates are elevated in the upper river below Minneapolis-St. Paul, Minn. Turbidity and solids are high downstream from the confluence with the Missouri River.

- *Eutrophication Potential.* Limited data are available to assess eutrophication directly. However, phosphorus levels increase moving downstream, with an increase in the lower river (below the Ohio River) in the past 5 years, while the upper river remains unchanged. Ammonia and nitrates increase significantly below Minneapolis-St. Paul. Although no algal growths were reported, phosphorus and nitrogen are present in quantities sufficient to support algae growths, and levels are generally getting worse.

- *Salinity, Acidity, and Alkalinity.* The only noticeable salinity and acidity problems occur below the inflows of the major tributaries. For example, dissolved salts, particularly sulfates, increase just below the Missouri River, and alkalinity decreases just below the more acid Ohio River inflow.

- *Oxygen Depletion.* Dissolved oxygen levels are satisfactory throughout the river, except for occasionally low levels below Minneapolis-St. Paul. BOD_5 and other parameters associated with sewage contamination indicate urban areas as the primary polluters along the upper river, and similarily, but less so, on the lower river. The oxygen parameters improved over most of the river in the past 5 years, with a significant improvement below Minneapolis-St. Paul since 1966 when secondary sewage treatment started.

- *Health Hazards and Aesthetic Degradation.* Fecal coliform counts are high throughout the Mississippi River, with peaks below urban centers, especially below Minneapolis-St. Paul. These counts exceed the levels desirable for primary contact recreation and drinking water supply intakes. Phenols and hydrocarbons are probably the major reasons for the elimination of commercial fishing below St. Louis, Mo., and Baton Rouge, La.

GENERAL PHYSICAL DESCRIPTION

The Mississippi River is the longest river in the United States in terms of drainage area, the largest in terms of annual average flow (620,000 cfs), and the second longest river (2,348 miles). The headwaters are in upper Minnesota, and its mouth is at the Gulf of Mexico near New Orleans, La. (Figure III-1).

A number of impoundments affect the flow of the upper Mississippi. The six impoundments on its headwaters have a combined capacity of 1.6 million acre-feet. Intended primarily to ensure sufficient flow for navigation, these impoundments do not materially affect flood flow. Similarly, the 27 dams associated with locks create pools but do not affect high flow conditions. Average flow at St. Paul for the past 5 years is 13,500 cfs, with a second quarter high flow of 26,600 cfs (Table III-1). Winter freezes reach the pooled areas above Alton, Ill., and

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Figure III-1

MISSISSIPPI RIVER

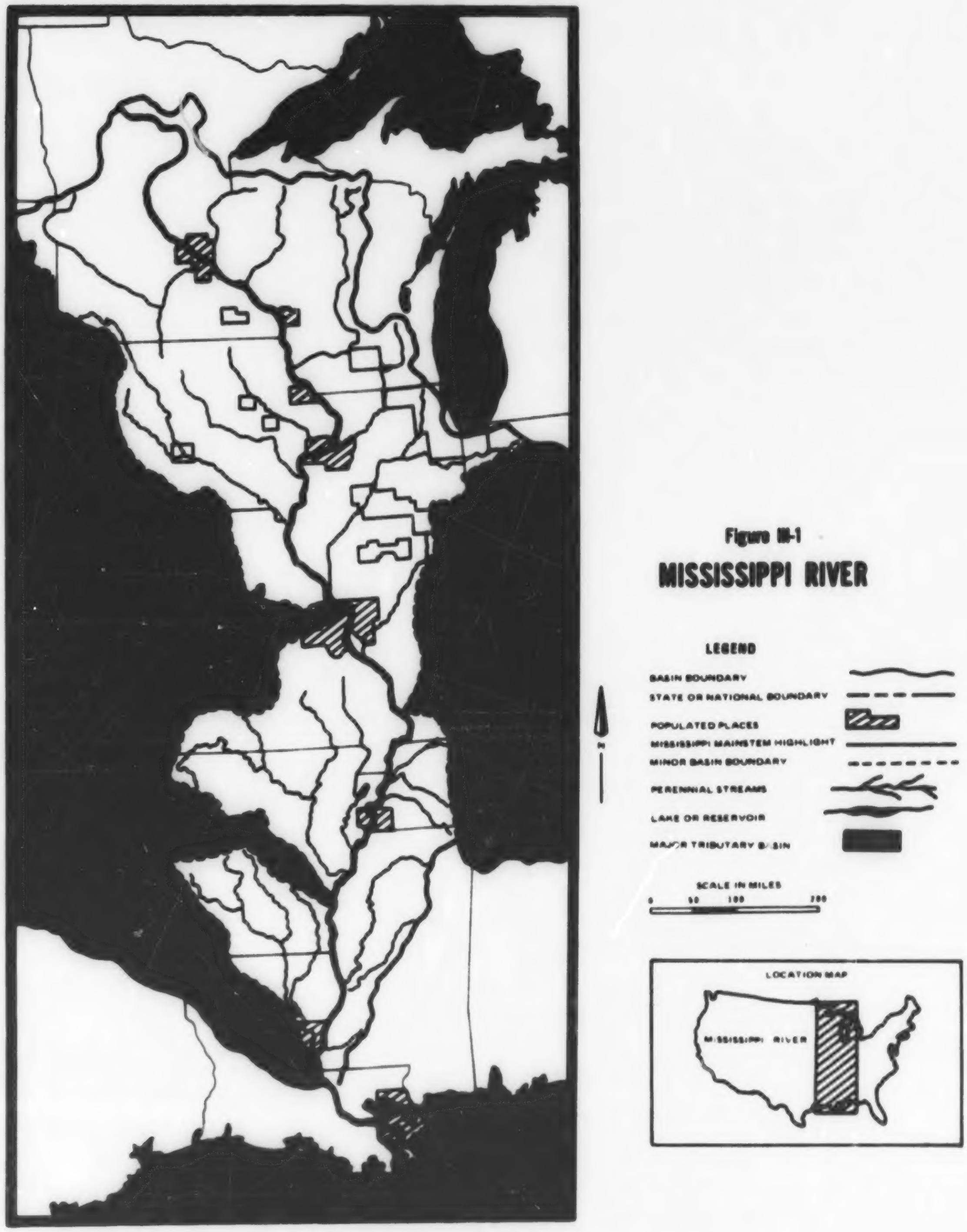

LEGEND
BASIN BOUNDARY
STATE OR NATIONAL BOUNDARY
POPULATED PLACES
MISSISSIPPI MAINSTEM HIGHLIGHT
MINOR BASIN BOUNDARY
PERENNIAL STREAMS
LAKE OR RESERVOIR
MAJOR TRIBUTARY BASIN
SCALE IN MILES
0
50
100
200
N
LOCATION MAP
MISSISSIPPI RIVER

TABLE III - 1

MISSISSIPPI RIVER STREAM FLOWS, 1963-1972

Location (river miles from mouth)	Years	Quarters 1st	 2nd	 3rd	 4th	Annual average
		(Mean flow in cubic feet per second)				
St. Paul, Minn. (1,793.1)	1963-67	8	29	9	7	13
	1968-72	7	27	8	12	13
Clinton, Iowa (1,465.6)	1963-67	40	81	31	29	45
	1968-72	35	79	40	42	49
St. Louis, Mo. (1,138.8)	1963-67	119	245	130	108	150
	1968-72	160	270	178	165	193
Memphis, Tenn. (731.5)	1963-67	496	580	246	276	400
	1968-72	596	619	318	334	467
Near Vicksburg, Miss. (430.4)	1963-67	549	700	304	317	468
	1968-72	745	775	377	411	577

sometimes as far as St. Louis. Forest, woodland, and cropland with pasture constitute the major land uses along the upper river.

Below the confluence of the Missouri, the large reservoir system of that river contributes significantly to the 100,000 to 300,000 cfs flow of the Mississippi. At Memphis, Tenn., the yearly average flow is from 400,000 to 500,000 cfs, and at Vicksburg, Miss., from 450,000 to 600,000 cfs, with the second quarter consistently the highest. The lower Mississippi river passes through a major cropland area from Cairo, Ill., through Helena, Ark. Other sections include grazing lands, swamp, and marshland, particularly near the mouth of the river. The heaviest industrial concentrations on the river, primarily petrochemical, lie from the Baton Rouge area to the Gulf. The Mississippi diverges into a number of passes before reaching the Gulf, and river mileage in this report follows the convention of expressing miles above the Head of Passes, La., where the South and Southwest Passes split from the Pass a' Loutre.

Minneapolis and St. Paul are the largest cities above the confluence of the Missouri. The Minneapolis-St. Paul Sanitary District provides waste treatment for the two cities. St. Louis lies a short distance below the Missouri, and Memphis lies about 200 miles below the tributary with the highest flow, the Ohio River. Baton Rouge and New Orleans lie 230 and 100 miles above the Head of Passes, respectively.

The relative size of the Mississippi in terms of stream flow is important in determining the possible effects of point sources. The ratio of population to stream flow is a rough indicator of the potential impact of activity on a river. At Minneapolis St. Paul, the ratio is 144, 12 times the ratio at St. Louis (12.4) and 75 to 85 times the ratios at Memphis (1.69) and New Orleans (1.87) (Table III-2).

DATA AND METHOD

The data for analysis come from 96 stations. The U.S. Geological Survey has had 15 stations and EPA 10 along the length of the river collecting a wide range measurements at weekly to monthly intervals. Two groups of stations in the Minneapolis area, established in connection with an EPA enforcement project, concentrated on parameters associated with municipal discharge during their periods of operation (1965-1970 and 1964-1965). Stations

TABLE III-2

MISSISSIPPI RIVER: SELECTED URBAN AREAS

Urban area	Population	Annual streamflow (cubic feet per second)	Population per cfs streamflow
Minneapolis-St. Paul, Minn.	1,870,000	13,000	144
St. Louis, Mo.	2,400,000	193,000	12.4
Memphis, Tenn.	790,000	467,000	1.69
New Orleans, La.	1,080,000	577,000	1.87

connected with an enforcement project on the lower Mississippi collected primarily pesticide data. Few stations have data over the entire period of study (1963-1972).

On the river profiles, cities with populations above 10,000 are marked as urban point sources at the location of their waste discharge outfalls (if they are known). Industrial sources indicate groups of plants designated as major dischargers by EPA Regional Offices. Urban areas are SMSA's, while agricultural areas are those indicated as "primary cropland" on the National Atlas land use map.

Some obvious sources of uncertainty face a water quality analysis of the Mississippi. Data come from points scattered along the river, so a problem might escape attention for lack of a station nearby. The size of the Mississippi reduces this difficulty, as few point sources are large enough by themselves to affect the river as a whole. Available data are particularly sparse on the lower river. Time variability of data presents a problem due to differences between stations in times of observations and periods of operation. For example, one agency operated a large number of stations in the Minneapolis-St. Paul area with similar observation frequency and period of record, facilitating study of that region but providing data which are not necessarily compatible with stations in other areas. This report attempts to discern patterns and trends that clearly stand out despite these uncertainties.

WATER QUALITY CONDITIONS

Physical Modification

Relatively low levels of both turbidity and total solids characterize the Mississippi above Minneapolis. Downstream, turbidity and total solids increase. Turbidity rises dramatically at the confluence of the highly turbid Missouri River and remains high throughout the lower river. Total solids levels are raised most significantly near cities, although levels decrease slightly in the lower river, possibly owing to the high flow of the Mississippi.

Total solids increase steadily from 190 mg/l in the headwaters to 250 mg/l at Dubuque, Iowa, and 400 mg/l at St. Louis, except for a spike of 350 mg/l at St. Paul. A high level (median of 436 and 85 percentile of 734) at Hickman, Ky., declines to a median of 278 at Memphis, with subsequent high levels of 416 mg/l decreasing to 313 mg/l at New Orleans.

Eutrophication Potential

Both inorganic nitrogen and phosphorus show peak concentrations near metropolitan areas. Phosphorus levels are generally high elsewhere, as well.

Nitrate concentrations slightly over 1 mg/l typify the Mississippi River. Median nitrate concentrations, around 0.1 mg/l in the headwaters, rise above 2 mg/l in the Minneapolis area. The median falls to 0.9 mg/l at Dubuque, but the 85th percentile is 1.6 mg/l. Medians for the rest of the river to New Orleans lie between 1 and 2 mg/l, with the exception of East St. Louis, Ill., with 2.7 mg/l and Helena, Ark., with 0.75 mg/l. The median at New Orleans is 0.92 mg/l, with highest concentrations in the second quarter. Burlington, Iowa, reports highest concentrations in the fourth quarter. Lack of data precludes seasonal analysis at other stations. The available data do not demonstrate changes between the 5-year periods studied.

Ammonia medians for the past 5 years lie near 0.1 mg/l for stations along most of the river, without significant seasonal variation or change from the previous 5 years (Figure III-2). St. Louis reports a slightly higher median of 0.2 mg/l. The Minneapolis-St. Paul and Davenport, Iowa areas, however, have much higher levels. Most of the data for this region, including all observations above 1 mg/l, come from the first quarter. These high ammonia levels thus reflect the nearly anaerobic state that accompanies the low-flow, high-BOD conditions under ice cover.

The 5-year median for phosphorus is near 0.1 mg/l upriver of Minneapolis, but downriver to St. Louis most stations report medians around 0.2 mg/l. The medians in the St. Louis area lie around 0.3 mg/l. Downriver stations report medians below 0.2 mg/l, except Vicksburg and New Orleans, both with 0.28 mg/l. The upper river does not change between 5-year periods, while total phosphorus concentrations have increased nearly 0.1 mg/l on the lower river.

Salinity, Acidity, and Alkalinity

The Mississippi River appears to be degraded by solids primarily near large cities. Alkalinity, chlorides, dissolved solids, and sulfate generally show elevated levels around Minneapolis and St. Louis. The lower river, with is larger flow, records lower pollutant levels, although at both Vicksburg and New Orleans the water is of relatively poorer quality.

For pH, 5-year medians lie between 7.8 and 8.0 for most of the river, with medians in the Vicksburg-to-New Orleans segment of 7.3 to 7.5. Seasonal variability is not significant except for a lower median (7.6) for the upper river in the first quarter. Medians for total alkalinity lie between 130 and 150 mg/l from the headwaters to Cairo, Ill., with a slight increase in the Minneapolis area. Below the confluence of the less alkaline Ohio, medians fall to around 100 mg/l, except for a median of 56 mg/l at Vicksburg coincident with the beginning of the stretch with lower pH. Total hardness is near 160 mg/l for nearly all reporting stations. Chlorides are below 5 mg/l above Minneapolis but rise to 30 mg/l in the Minneapolis area. Medians of 10 mg/l below Minneapolis rise to 20 mg/l at St. Louis and 31 mg/l at New Orleans. Sulfate medians range from 10 to 40 mg/l above St. Louis, 60-80 mg/l to Cape Girardeau, Mo., and around 50 mg/l below the confluence of the Ohio. The median dissolved solids concentration is 275 mg/l at St. Paul, and medians range from 200 mg/l to 240 mg/l from St. Paul to Burlington. From Burlington to Cape Girardeau the medians are near 300 mg/l. The levels are lower and highly variable further downstream.

Oxygen Depletion

Degrading effects of point sources are superimposed on the river's otherwise satisfactory oxygen levels. Large cities appear to be the main pollution sources, producing low oxygen levels immediately downstream, and gradual recovery further downstream. The dissolved oxygen medians for 1968-72 fall to extremely low levels near Minneapolis; however, all quarters except the third show considerable improvement from 1963-67 levels (Figure III-3).

In the first quarter, near Minneapolis, the median falls as low as 4.1 mg/l, owing in part to ice cover. During the third quarter, with relatively high temperatures and less flow than the second quarter, a station 10 miles downstream from the outfall recorded a dissolved oxygen median of 2.5 mg/l, with 15 percent of the observations below 0.35 mg/l. Although oxygen levels are sometimes low enough to endanger fish, no reported fish kills have been attributed to oxygen depletion. The 1968 Federal criterion for fresh-water fish specifies that dissolved oxygen should be "at or near saturation" for cold water species; median saturations below Minneapolis fall to 30 percent in both the first and third quarters.

Figure III-2 RIVER PROFILE

MISSISSIPPI RIVER

AMMONIA

1968-1972 DATA

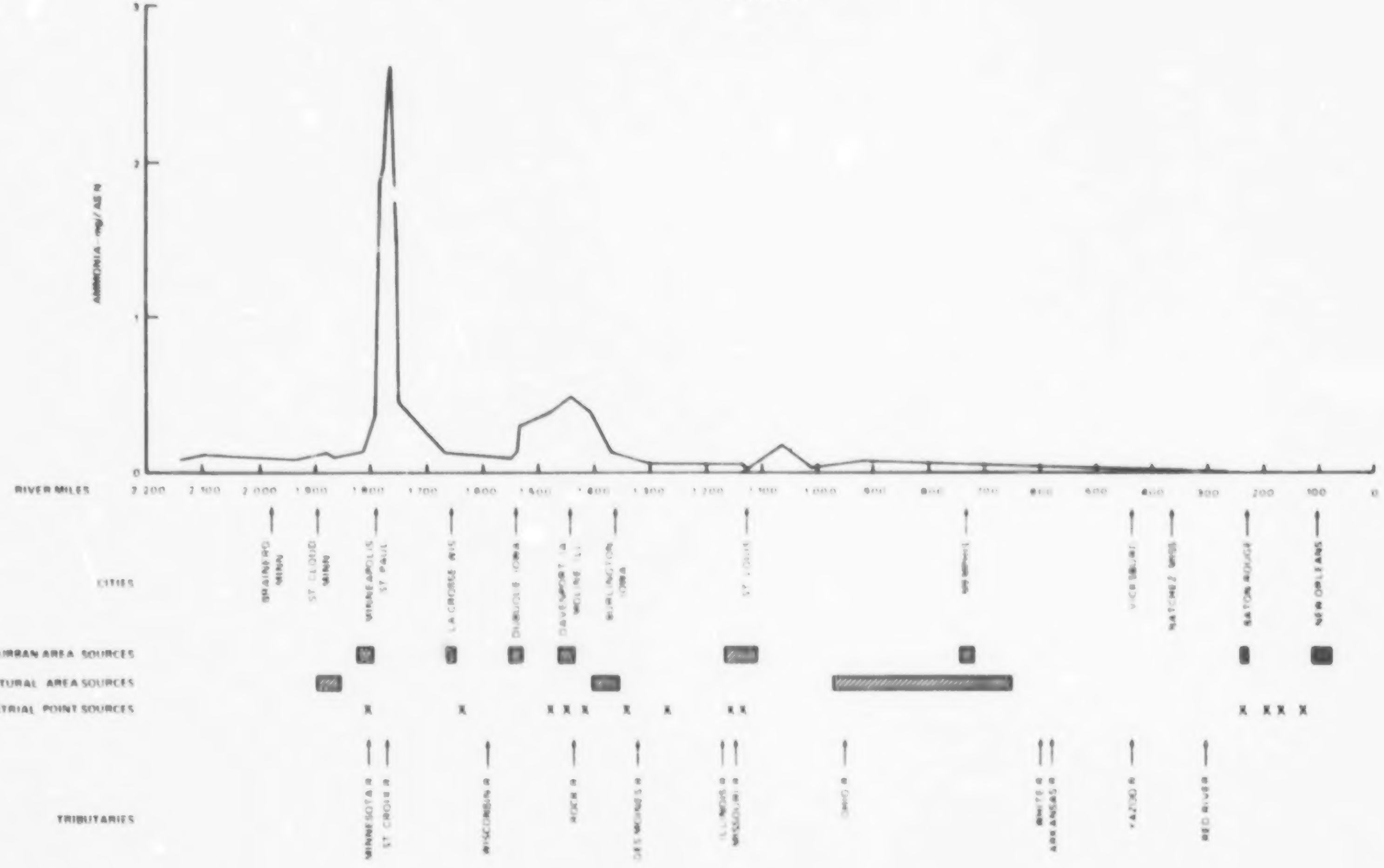
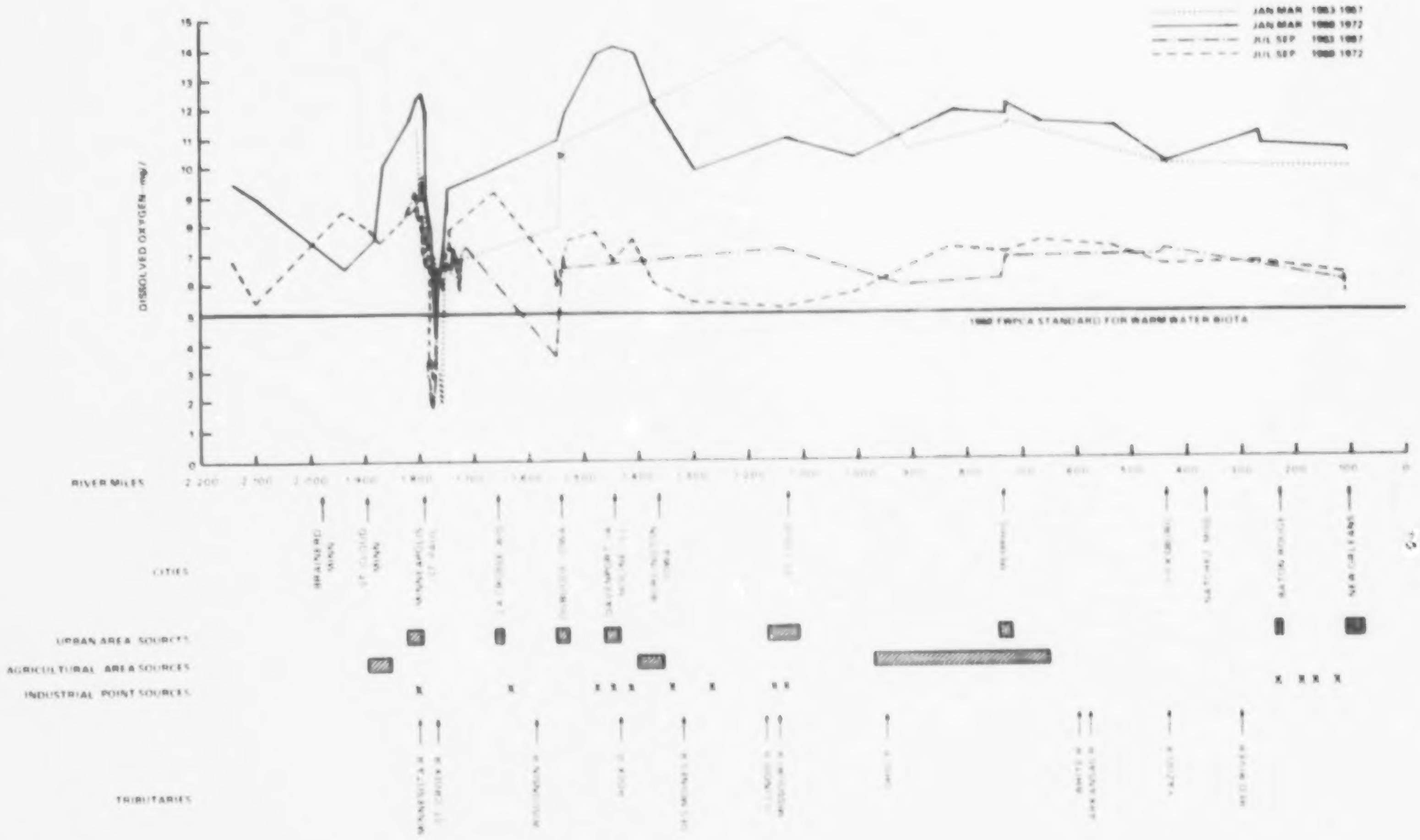


Figure III.3 SEASONAL RIVER PROFILES

MISSISSIPPI RIVER

DISSOLVED OXYGEN



Upriver from Minneapolis, BOD_5 medians are between 2 and 3 mg/l, with the first and fourth quarters slightly lower than the third and high flow second quarters (Figure III-4). Flow is generally three to five times greater in the second quarter than in the first, so that the total load of BOD_5 is significantly greater in the second; this seasonal pattern suggests a runoff or scouring effect in the river above Minneapolis. BOD_5 concentrations increase to 10 mg/l from the Minneapolis-St. Paul Sanitary District (MSSD) outfall, producing higher concentrations in the lower flow quarters. Six miles downstream from the outfall, the first quarter 1968-72 median is 14.3 mg/l. Within 40 miles, medians for all quarters stabilize near 3.4 mg/l.

While the upstream stations demonstrate no major change between 1963-67 and 1968-72, the Minneapolis area has improved, particularly in the first and fourth quarters. Some stations report medians for these quarters as much as 3 or 4 mg/l higher in the first 5 years than in the second. MSSD began implementing secondary waste treatment in 1966, probably causing the improvement. Comparison of the periods 1964-65, 1966-67, and 1968-69 shows improvement between the first two of these three periods, but little difference between the second and third (Table III-3).

The 1968-72 dissolved oxygen median is 8 mg/l, 40 miles below St. Paul, and varies between 8 and 10 mg/l at downriver stations, except for St. Louis with 7.4, Cape Girardeau with 7.0, and New Orleans with 6.8 mg/l. The first quarter is uniformly the best with medians from 13 to 10 mg/l, generally decreasing downstream except for a stretch of 10 mg/l from St. Louis to Cape Girardeau. Other quarters follow the same pattern at low levels, with stations reporting medians about 5 mg/l less in the worst quarter (the third) than in the first. Although all medians from 1968-72 on the lower river exceed the 1968 Federal criterion for warm water species (5 mg/l), many stations report some observations below that level. Temperature differences account for most of the decrease between season, as the dissolved oxygen saturation profiles demonstrate, but the median saturations in the middle river do fall from around 85 percent in the first quarter to near 70 percent in the third (Figure III-5).

Downstream from Minneapolis, BOD_5 medians are relatively low. The median is 3.4 mg/l near Dubuque, and rises to near 4 at Burlington. Readings are lower downstream, with a 1968-72 median of 1.3 mg/l at West Memphis. At Helena, Ark., the level is 3.1 mg/l, probably due to BOD_5 loadings in the Memphis area. The medians are again lower downstream, with 1 mg/l at New Orleans. The third quarter consistently has the lowest BOD_5 concentration, and the first quarter the highest.

Where data are available, medians below St. Paul for 1963-67 do not significantly differ from those for 1968-72, except to indicate a 0.5 mg/l improvement at Dubuque.

Health Hazards and Aesthetic Degradation

The highest total and fecal coliform levels appear to be located near the large population centers (Figures III-6 and III-7). The levels observed, particularly the high counts below the major urban centers, indicate contamination of the river by the municipal treatment plants and sewer systems. The shape of this profile closely resembles the shape of the profiles for BOD_5 and for total solids, except for a low median count at Alton in a stretch of the river with high BOD_5. The correspondence might suggest that much of the BOD_5 load from the Minneapolis-St. Paul, St. Louis, and Memphis areas comes specifically from the municipal dischargers.

Not enough concentration data on hydrocarbons and phenols are available to prepare a complete profile. Definite problems do exist on the lower river, however, as evidenced by taste contamination of fish and taste and odor problems with public water supplies.

Data availability and differences in measurement of total coliforms present difficulties for an upper river analysis. Medians of 2,000-6,000 per 100 ml occur above Minneapolis, with levels about 100,000 frequently found below the MSSD outfall. One station 40 miles below St. Paul, with frequent observations from 1963-69, reported a median of 20,000 for the first 5 years but 9,000 for the later period. The middle river from Burlington to Memphis has improved considerably from the previous 5-year period. The total coliform levels of the lower river have increased slightly, with the net effect that the distributions are fairly uniform along the river. Although counts vary

Figure III-4 SEASONAL RIVER PROFILES

MISSISSIPPI RIVER

BIOCHEMICAL OXYGEN DEMAND

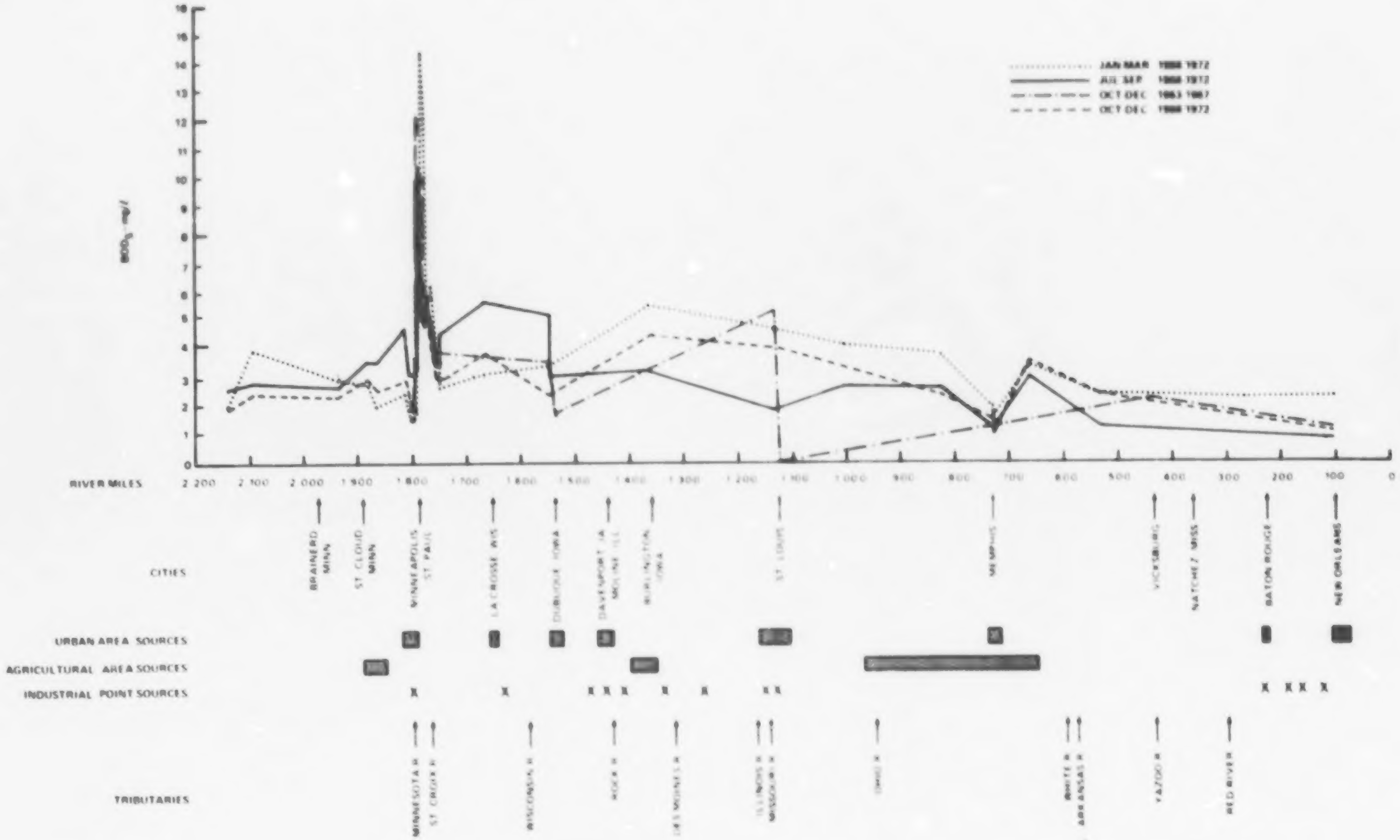


TABLE III-3

MISSISSIPPI RIVER: BOD, NEAR MINNEAPOLIS, 1964-69

Location (river miles from mouth)	Years	No. of samples	15th Percentile	Median	85th Percentile
				(BOD, in mg/l)	
Station 30* (1,784.1)	1964-65	89	5.9	8.7	19.7
	1966-67	94	5.0	7.6‡	12.4
	1968-69	69	5.3	7.3	14.3
Station 28† (1,708.3)	1964-65	91	5.2	8.8	16.0
	1966-67	90	5.0	6.7‡	10.6
	1968-69	63	4.9	6.5	11.2

*STORET station number 260030, operated by user number 1110R050.

†STORET station number 260028, operated by user number 1110R050.

‡Decrease from 1964-65 level significant at .003-.006 confidence level using Mann-Whitney U Test for statistical significance.

greatly from observation to observation, the median in the lower two-thirds of the river falls around 3,000 to 5,000, with Cape Girardeau and Memphis higher (10,000) and New Orleans lower (1,500). The variability of the bacterial level obscures any seasonal trend except a worsening of the Minneapolis area in the fourth quarter.

Almost all medians exceeded the 1968 Federal criterion for primary recreation (log mean of 200 per 100 ml), and many readings exceeded the standards for public water supplies (2,000 per 100 ml). Stations upstream of Minneapolis report medians for the past 5 years of 500 or below, but 85th percentiles as high as 7,000. Extreme levels exist close below the MSSD outfall, with a median of 78,000 and 15 percent of the observations above 330,000 at a station 6 miles below the outfall. Downstream of St. Paul, fecal coliform counts fall to relatively low levels, but medians exceed 1,000 at Canton and Cape Girardeau. Below Cape Girardeau, levels decline to Memphis, then rise above 1,000 before resuming the decrease to New Orleans.

Below Baton Rouge and from St. Louis to Cape Girardeau, taste tainting of fish prevents commercial fishing despite the presence of fish. "Industrial Pollution of the Lower Mississippi River in Louisiana", published by the EPA in April 1972, attributes the problems to industrial waste discharges. "The Report on the Effect of the St. Louis Metropolitan Area on Water Quality in the Mississippi River", published by the Federal Water Quality Administration in December 1969, identifies phenols as a cause of taste and odor problems, and mentions chemical manufacturing plants and oil refineries as their primary source. This tainting is the most readily apparent effect of industrial pollution on the Mississippi. Reports from the upper river do not indicate taste contamination of fish as a major problem, but do show that the commercial fish catch has remained at a fairly stable size for many years.

Phenols were found in the St. Louis area in December 1969 for the Missouri and Illinois sides of the Mississippi River from the Missouri River to 100 miles downstream (Figure III-8). The conditions over the past 5 years are not as severe as the December 1969 period; however, they do indicate high phenol levels that persist for more than 100 miles downstream at levels that interfere with water supplies and can cause fish tainting.

Figure III-5 SEASONAL RIVER PROFILES

MISSISSIPPI RIVER

DISSOLVED OXYGEN

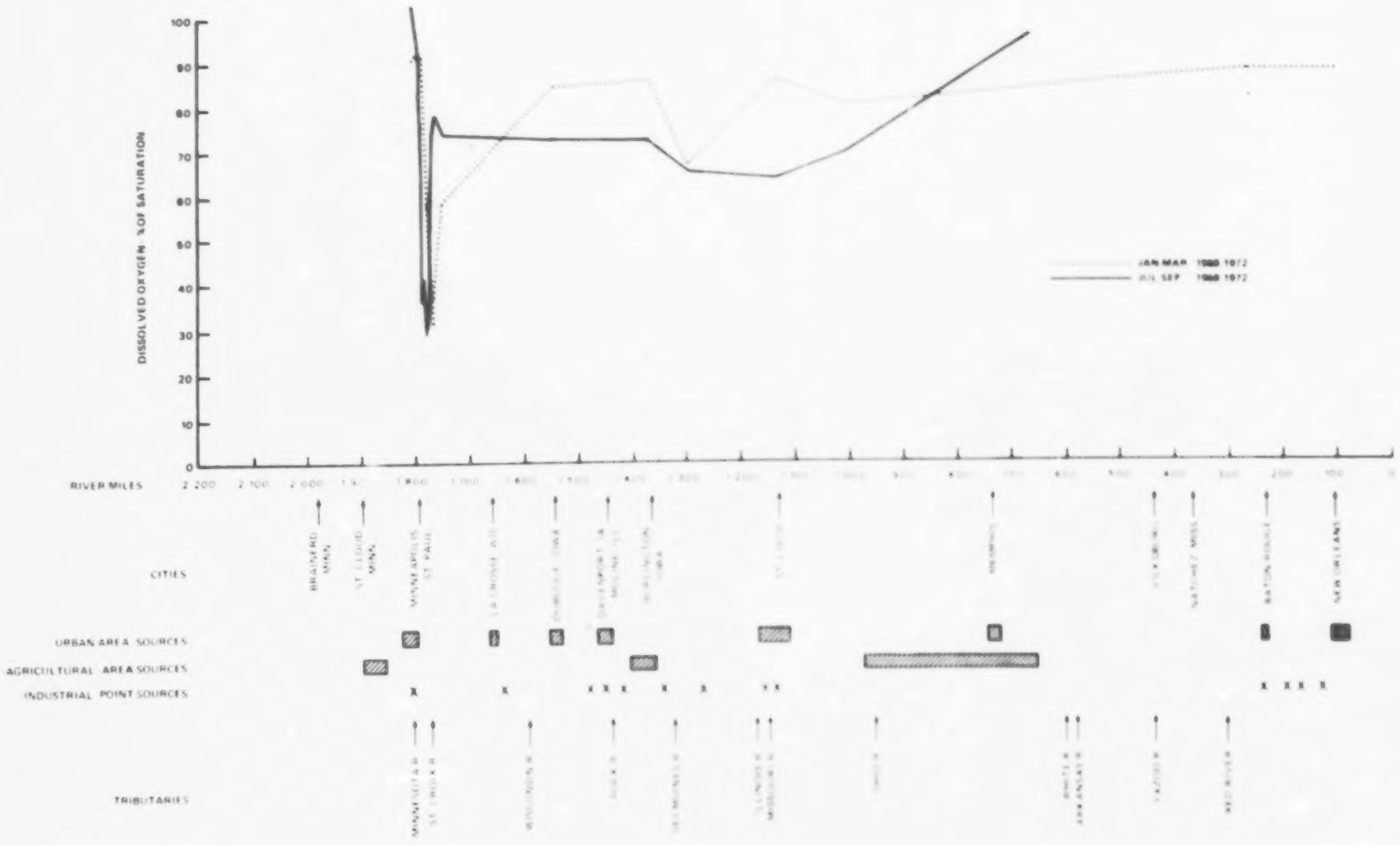


Figure III-6 **RIVER PROFILE**

MISSISSIPPI RIVER

TOTAL COLIFORMS

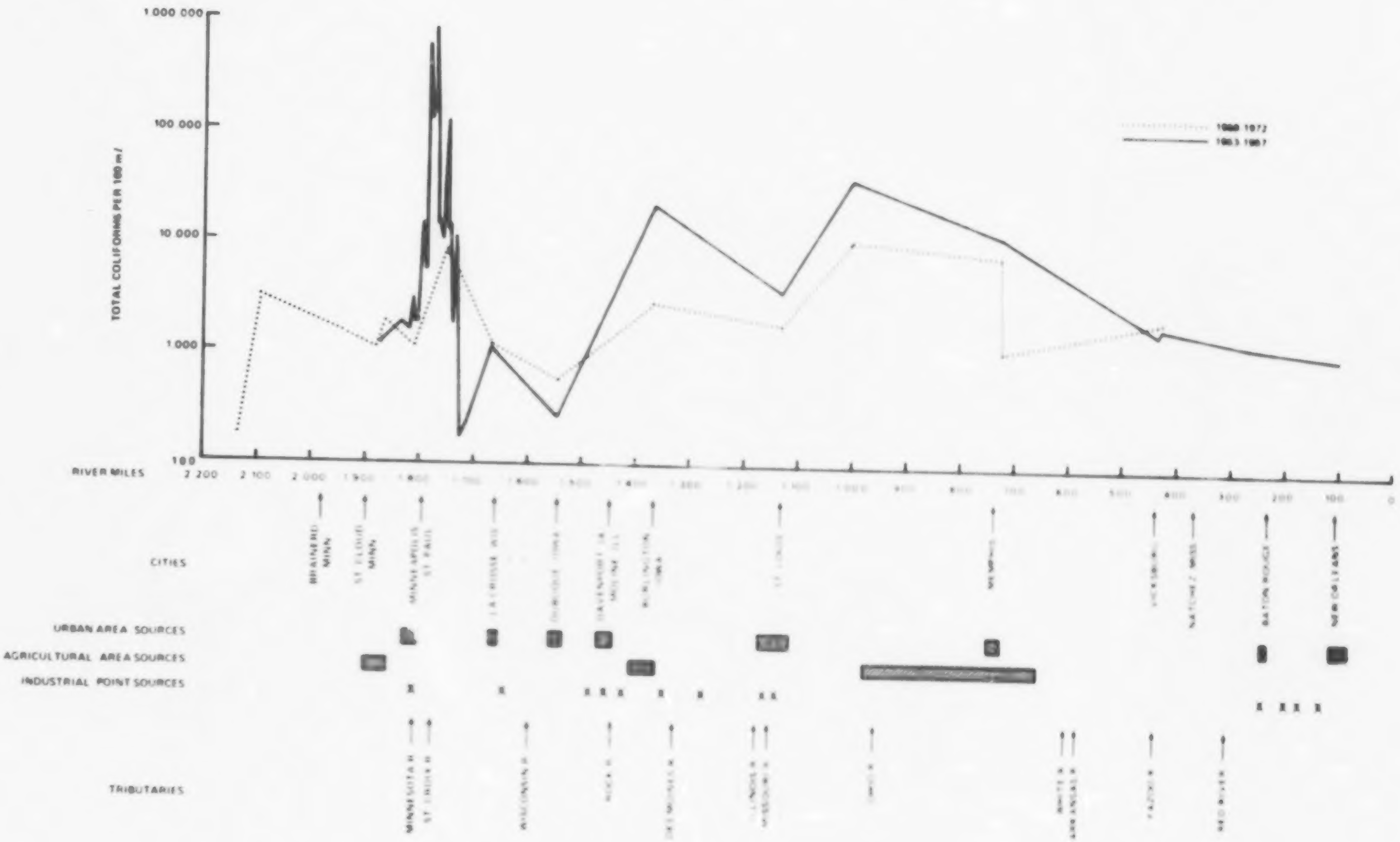


Figure III-7 **RIVER PROFILE**

MISSISSIPPI RIVER

FECAL COLIFORMS

1968 - 1972 DATA

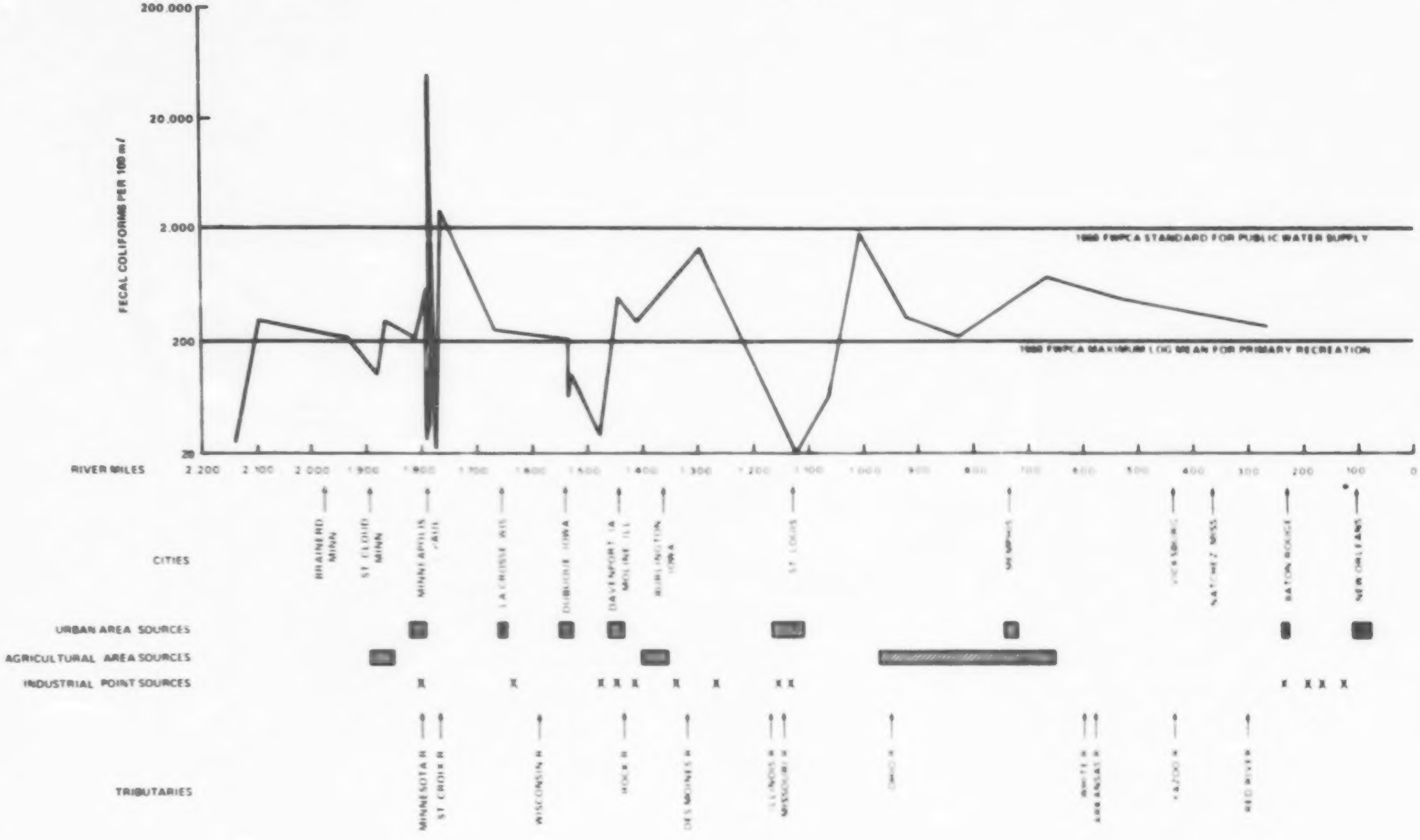
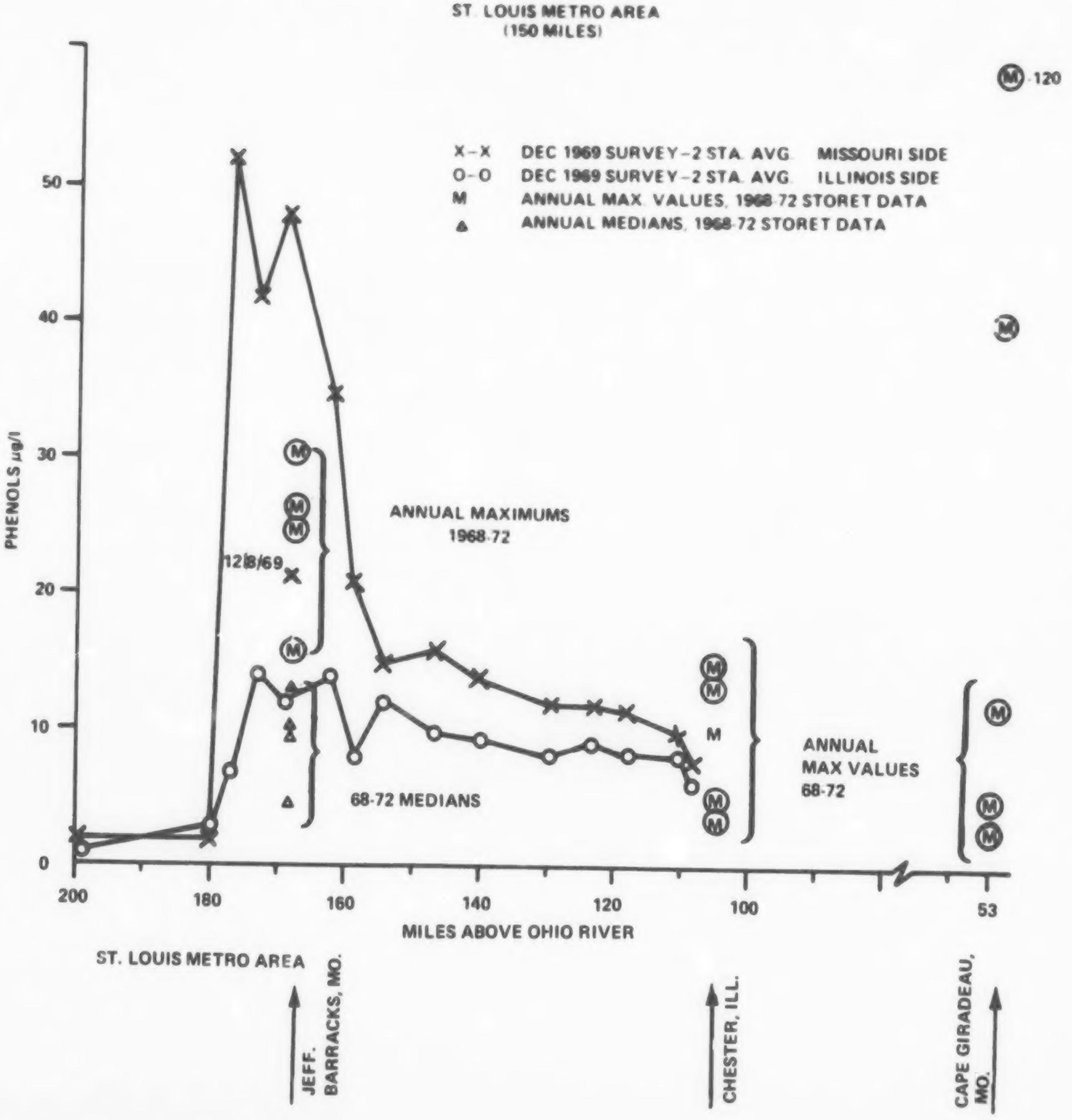


Figure III-8 RIVER PROFILES

MISSISSIPPI RIVER

PHENOLS



IV. MISSOURI RIVER

The most significant types of pollution in the Missouri River appear to be physical degradation (primarily related to erosion) and potential health hazards (organic pollutants near major cities), according to routine water monitoring data for 1963-72. Special studies confirm the presence of undesirable bacteria and viruses and tainting of fish flesh downstream of several large cities. These biological problems, apparently arising from point sources in metropolitan areas, are masked on about 9 to 16 percent of the days by pollutants associated with runoff following heavy rains.

The key pollutants highlight conditions in the Missouri:

- *Harmful Substances.* Trace metals are present, particularly in the middle segment of the Missouri from Yankton, S.D., to Kansas City, Mo., and in some cases concentrations are rising. However, the more toxic metals have not exceeded levels generally considered permissible for water supply intakes.

- *Physical Modification.* The middle and lower segments of the Missouri experience some of the heaviest sediment erosion in the United States, producing high suspended solids and turbidity in the river. After rainfalls, pollutants washed from farms and cities are carried with the soil and add organic matter, nutrients, bacteria, and salts to the river.

- *Eutrophication Potential.* No nuisance algal growths have been reported, even though phosphates and nitrogen are present in the middle and lower Missouri in high enough concentrations to support growths, and were generally getting worse over the 1963-72 period. Other factors, such as channelization, flow augmentation, and natural turbidity, limit the eutrophication potential.

- *Salinity, Acidity, and Alkalinity.* Dissolved salts, particularly sulfates, reach and often exceed national guidelines for water supply intakes in the middle and lower Missouri. The salts arise from both natural conditions and an increasing amount of irrigation in the upper Missouri. Future development of coal resources in the upper basin may aggravate the problem.

- *Oxygen Depletion.* Organic loadings in the Missouri arise in part from heavy animal feedlot runoff from Kansas, Nebraska, and Iowa. At times, loadings are high enough to deplete dissolved oxygen below recommended levels for fish. BOD_5 and COD improved near large cities in the past 5 years compared to the preceding 5 years.

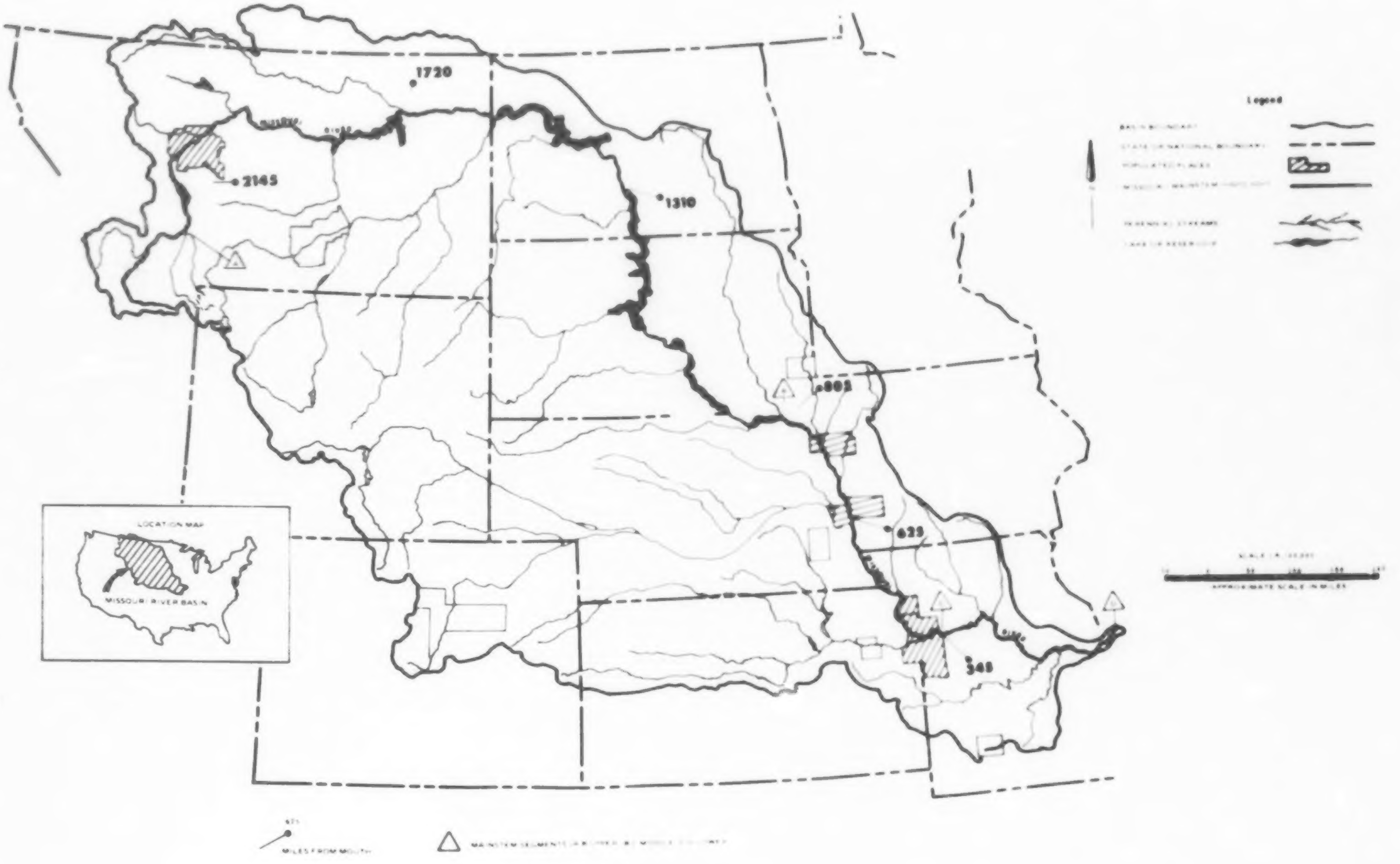
- *Health Hazards and Aesthetic Degradation.* Fecal coliform levels peak well in excess of water quality standards for swimming and drinking downstream from urban areas in both wet and dry periods, as do other measures of fecal contamination (coprostanol) and viruses. Both point sources and runoff are probably responsible.

GENERAL PHYSICAL DESCRIPTION

The Missouri River basin is the largest in the United States, covering an area of 513,300 square miles in the United States and 9,700 square miles in Canada. There are 14 major tributaries—Yellowstone, Little Missouri, Cheyenne, Niobrara, Platte, Kansas, Osage, and Gasconade in the South and West and the Milk, James, Big Sioux, Little Sioux, Grande, and Chariton from the North and East—along the 2,315 miles of the main stem of the river (Figure IV-1). The 1898-1966 mean annual flow for the Missouri at Hermann, Mo., was 56.7 million acre-feet, with a 1915 maximum of 105 million acre-feet and a 1934 minimum of 22 million acre-feet.

Figure IV-1 **BASIN MAP**

MISSOURI RIVER


1720
2145
1310
802
623
348
MISSOURI RIVER
LOCATION MAP
MISSOURI RIVER BASIN
Legend
BASIN BOUNDARY
STATE OR NATIONAL BOUNDARY
POPULATED PLACES
MISSOURI MAINSTEM
PERENNIAL STREAMS
LAKE OR RESERVOIR
0
50
100
150
APPROXIMATE SCALE IN MILES
MILES FROM MOUTH
MAINSTEM SEGMENTS

Of the 11 major urban areas (Standard Metropolitan Statistical Areas) in the basin, five are on the main stem representing a 1970 population of 2.1 million (Table IV-1). In addition there are 79 smaller cities and towns along the main stem having a 1970 population of 394,000.

Economy in the basin is geared around agriculture, primarily fine grains and meat. The largest manufacturing segment is the processing of food, with meat packing being the largest single food-processing industry. Livestock markets and meat-packing plants are basic to the economies of Sioux Falls, Sioux City, Omaha, and St. Joseph, with a trend toward decentralizing plants throughout the basin. Of the 132 million acres of agricultural land (95 percent of the basin), 61 percent is used for grazing on pasture, range, and forest lands. Croplands account for 104 million acres, of which 7 percent is irrigated.

Land and water resources in the basin had recreation use in 1965 of 331 million activity days, with swimming, fishing, boating, and water skiing comprising 30 percent of the total. While most of the recreation occurs in the upper segment of the basin, 35 percent occurs in the more densely populated middle and lower segments of the basin. Commercial fishermen harvested 5.2 million pounds of fish in 1965. Fishing waters of the basin include 43,500 miles of streams and 1,422,000 surface acres of impounded waters and natural lakes.

Climate varies across the basin, with annual average precipitation ranging from over 40 inches in parts of the Rocky Mountains and Southeastern parts of the basin to as low as 6 to 12 inches immediately east of the Rocky Mountains. Runoff entering the streams varies similarly, with less than 1 inch annually in the plains area to over 10 inches in the mountains and Ozark Plateau areas. Precipitation received from November through March generally is in the form of snowfall. Thunderstorms are prevalent in July and August and often are localized with high-intensity rainfall. There are prolonged droughts interspersed with periods of abundant precipitation. Winters can be extremely cold (-60°F in mountains) and summers hot (up to 120°F in Nebraska, Kansas, and Missouri).

TABLE IV-1

MISSOURI RIVER MAIN STEM: SUMMARY OF POPULATION AND WATER STATISTICS

	Main stem segments			
	Upper (RM799-2,227)	Middle (RM340-799)	Lower (RM0-340)	Total (RM0-2,227)
No. Standard Metropolitan Statistical Areas (SMSA's)	1	4	0	5
No. cities (ex. SMSA's)	32	24	23	79
No. cities over 10,000 (ex. SMSA's)	4	4	3	11
SMSA population (1970)	81,804	2,001,088	0	2,082,892
Total population (1970)	200,416	2,215,269	158,645	2,574,330
No. major industries (MICS)	6	14	2	22
Water supplies-river (1963)	11	8	8	27
Water supplies-wells (1963)	15	18	11	44
Population served by wells	29,660	234,736	57,220	321,616
Population served by river	162,365	1,152,405	805,500*	2,189,755

*Includes St. Louis water supply from lower Missouri River.

DATA AND METHOD

Routine monitoring data for 25 stations are available from the STORET system covering the 10-year period 1963-72. Data from special studies performed during 1968-70 and reported in EPA Region VII's report, *Everyone Can't Live Upstream - a Contemporary History of Water Quality Problems on the Missouri River, Sioux City, Iowa to Hermann, Missouri,* were used to supplement the routine monitoring data.

Analysis of the Missouri River was divided into three segments:

- The upper two-thirds, or 1,400 miles. The hydrology of this section is dominated by seven reservoirs that account for 785 of the 1,400 miles.
- The middle 400 miles, from Yankton to Kansas City. This section has 86 percent of the total main stem population and the greatest sediment and agricultural runoff. Erosion here produces 1,000 to 6,000 tons of sediment per square drainage mile each year (Figure IV-2). This segment also has most of the stockyards and meat-packing activity in the basin, as well as animal feedlots.
- The lower 400 miles, from Kansas City to the mouth of the river where it enters the Mississippi River at St. Louis.

The upper 1,400 miles of the Missouri had only six water quality stations, so only the middle and lower segments were analyzed in detail. Data analyses for the middle and lower sections consisted of three approaches: profiles to compare two 5-year periods (1963-67 versus 1968-72), analysis of seasonal differences, and analysis of specific high-streamflow and low-streamflow conditions. For these analyses, 20 water quality parameters were available (Table IV-2).

TABLE IV-2

MISSOURI RIVER WATER QUALITY PARAMETERS

Parameter	1963-67	1968-72
Stream flow - cfs	*	1969-72
Temperature - °Centigrade	*	1969-72
Turbidity - JTU	*	1968-71
DO - mg/l	*	1969-72
DO - % Saturation	*	1969-72
BOD$_5$ - mg/l	*	1969-72
COD - mg/l	*	1969-72
pH - Standard units	*	1969-72
Total alkalinity - mg/l	*	1969-72
Total hardness - mg/l	*	1969-72
Dissolved solids - mg/l	*	*
Suspended solids - mg/l	1963-66	None
Chlorides - mg/l	*	1969-72
Sulfates - mg/l	*	1969-72
Total phosphate - P mg/l	1964-67	1969-72
Ammonia nitrogen - N mg/l	1963-65	1969-72
Nitrate nitrogen - N mg/l	None	1969-71
Nitrate plus nitrite - N mg/l	1964-67	1971-72
Total coliform (delayed) - no./100 ml	*	*
Total coliform (immediate) - no./100 ml	None	1969-72
Fecal coliform - no./100 ml	None	1970-72

*Data available for entire 5-year period.

High- and low-streamflow conditions along the Missouri River are a product of its tributaries. Durations of runoff peaks were determined for selected tributaries (Table IV-3). Peak flows in the Missouri were determined by analyzing daily streamflow data (Table IV-4).

TABLE IV-3

MISSOURI RIVER: RUNOFF DURATION AND FREQUENCY FOR SELECTED TRIBUTARIES

Tributary	Location	Length of record (years)	% of time affected	Runoff peak duration (days/year)			Runoff peaks (no./year)		
				Avg	Min	Max	Avg	Min	Max
Kansas	Bonner Springs, Kans.	13	16	60	20	92	12	6	18
Platte (Iowa)	Agency, Iowa	13	14	53	22	86	14	8	24
Nishnabotna	Hamburg, Iowa	13	11	39	16	64	10	5	17
Little Sioux	Turin, Iowa	9	12	42	14	79	6	4	9
Big Sioux	Akron, Iowa	13	9	35	10	82	4	1	10

TABLE IV-4

MISSOURI RIVER: HIGH & LOW FLOW INTERVALS FOR MIDDLE & LOWER SEGMENTS

Year	July-October low flow (steady state)	March-May peak flow
1963		March 4-11 - May 5-22
1964	July 1-September 9 September 14-October 30	
1965	August 1-September 8 October 5-20	March 1-6 March 15-24 April 1-18
1966	July 1-October 30	
1967	July 16-September 30	
1968	July 1-25 September 1-October 10	
1969	August 1-September 6	March 18-May 3
1970	July 1-September 15	
1971	July 22-September 30	February 19-March 4 March 12-20 May 12-31
1972	NA	

WATER QUALITY CONDITIONS

Upper Segment

The upper 1,400 miles of the Missouri River main stem are dominated by seven reservoirs covering 785 miles (55 percent of the upper main stem length), providing a storage capacity of about 77 million acre-feet. The six sampling locations in this segment were too far apart to permit comparing time intervals and variations over season. The chemical, physical, and bacteriological data indicate generally good conditions in the upper segment (Table IV-5). Trace metals are discussed in the following section. Mining and irrigation in the upper basin have a degrading impact on water quality that becomes most critical in the middle segment; the lower segment receives tributary flows that tend to correct these problems.

Middle and Lower Segments

Harmful Substances. Limited data were available on radioactivity, trace metals, insecticides, and herbicides so that data for each river segment had to be aggregated to determine median values.

Radiological contamination (total alpha and beta) improved in 1968-72 over the earlier 5 years, with levels increasing in the downstream direction (Table IV-6). Special fall surveys in 1968 and 1969 found that dissolved radionuclide concentrations—uranium (U-235 and U-238), radium-226, thorium-232, total alpha thorium, and strontium-90—were substantially lower than permissible limits for public water supplies.

Trace metals are generally higher in the middle segment, between Yankton and Kansas City, than the upper and lower segments. The most noticeable changes between the two 5-year periods are for dissolved copper, dissolved strontium, and total iron (Table IV-7). No median or 85th percentile exceeds the rejection limits for drinking water established in the 1962 drinking water standards.

Analyses were available for 17 pesticides for the entire 10 years, but only for the 1968-72 period for herbicides. In the upper section of the river in 1963-67, DDE, DDT, and dieldrin were detected in 15 to 50 percent of observations, while in the middle section, aldrin, BHC, chlordane, DDT, and dieldrin were detected. The lower section had all the preceeding pesticides, plus DDD. During the 1968-72 period, no pesticides were detected in the upper segment; DDT and dieldrin were found occasionally in the middle and lower sections. Herbicides were found more frequently than pesticides, with 2,4-D being found in all three river segments; 2,4,5-T and Silvex were most prevalent in the lower segment, but were never found in the upper segment.

Physical Modification. The last major dam on the main stem was completed in the early 1960's. The water released from Gavins Point Dam at the lower end of the upper segment is the major factor affecting flows in the middle and lower segments during dry weather periods, with five significant tributaries—Big Sioux, Platte, Kansas, Grand, and Osage—significantly affecting flow during heavy rainfall periods.

In the upper river, reservoirs generally improve physical water quality by trapping solids. In the lower 800 miles, tributary inputs, urban areas, and river channelization for flood control and navigation increase suspended solids and turbidity: suspended solids increase dramatically moving downstream from Gavins Point Dam (37 mg/1) to the Kansas River (409 mg/l), and decrease below the Kansas River. During 1963-66, suspended solids exceeded 1,400 to 1,600 mg/l in 15 percent of the samples; data for 1968-72 showed lower levels and fewer fluctuations, even though flows were higher (33,000 compared to 26,000 cfs). Turbidity was very similar, increasing sharply (25 to 230 JTU) as the river flowed downstream over the entire lower 800 miles, except for a noticeable dip below Kansas City. Turbidity improved slightly in the reach between Omaha and Kansas City during the 1963-67 period, dropping from 230 to 160 JTU.

During the two 5-year periods, temperatures were very similar from Gavins Point Dam to the Kansas City area. The median for the 1963-67 period was 1-2°C higher than the 12-15°C medians for 1969-72.

TABLE IV-5

MISSOURI RIVER: SUMMARY OF CHEMICAL, PHYSICAL, AND BACTERIOLOGICAL DATA FOR UPPER RIVER (RM 810-2,227)

Parameter	Canyon Ferry Dam RM 2227		Fort Benton RM 2094		Wolf Point RM 1701		Culberston RM 1621		Williston RM 1554		Bismarck RM 1301	
	1963-67	1968-72	1963-67	1968-72	1962-67	1968-72	1963-67	1968-72	1963-67	1968-72	1963-67	1968-72
						(medians)						
Stream flow – cfs	–	–	–	–	13,000	12,000	13,000	12,000	17,000	22,000	20,000	31,000
Temperature-°Centigrade	–	–	–	–	14	5.5	10	7.5	11	6	8	9
Turbidity-JTU	–	–	–	8	–	–	–	43	25	60	30	25
DO-mg/l	–	–	–	11	–	–	–	9.6	11	–	11	11
BOD_5-mg/l	–	–	–	1.6	–	–	–	1.2	1.2	–	1.0	0.7
pH-Standard units	7.5	7.9	–	8.2	7.8	7.9	7.8	8.1	8.2	8.1	8.3	8.3
Total alkalinity-mg/l	122	133	–	147	155	161	157	163	158	166	150	144
Total hardness-mg/l	129	137	–	170	228	230	228	238	230	210	212	214
Dissolved solids-mg/l									470		543	428
Suspended solids-mg/l									71		41	
Chlorides-mg/l		8.5		7.6	8.2	8.0	8.4	8.2	10	10	9	9
Sulfates-mg/l	32	35		59	161	164	163	168	182	181	165	160
Total phosphate-P mg/l				0.11				0.11	0.06	0.12	0.04	0.03
Ammonia nitrogen-N mg/l				0.06				0.02	0.3	0.02	0.3	0.06
Nitrate nitrogen-N mg/l		0.01		0.13		0.01		0.02		0.13		0.18
Nitrate plus nitrite-N mg/l		0.01		0.08		0.01		0.04	0.10	0.10	0.10	0.17
Total coliform-no./100 ml									600	14	100	020
Fecal coliform-no./100 ml				15				18				

TABLE IV-6

MISSOURI RIVER: RADIOACTIVITY

	Upper segment		Middle segment		Lower segment	
	1963-67	1968-72	1963-67	1968-72	1963-69	1968-72
	(5-year medians in picocuries per liter)					
Alpha						
Total	4	4	9	5	9	8
Dissolved	3	3	4	3	3	3
Suspended	0	0	5	2	4	5
Beta						
Total	22	17	45	28	74	40
Dissolved	17	14	24	19	32	23
Suspended	3	2	21	10	32	20

TABLE IV-7

MISSOURI RIVER TRACE METALS

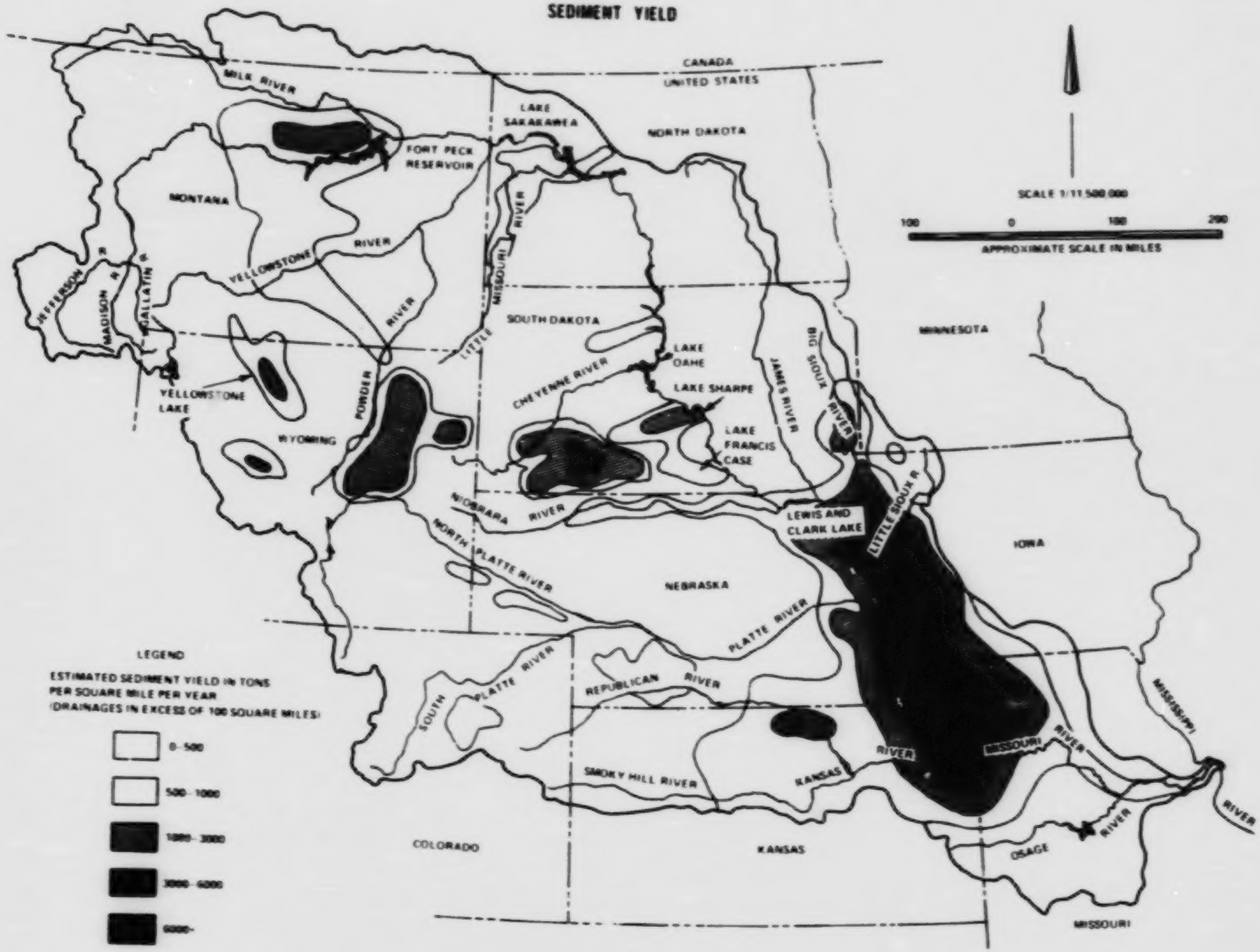
Metal (dissolved)	Upper segment		Middle segment		Lower segment	
	1968-72 median†	% change‡	1968-72 median	% change	1968-72 median	% change
	(micrograms per liter)					
Aluminum	—		64		62	
Arsenic	2		4		22	
Barium*	43		60		78	+81
Beryllium	0		0		0	
Boron*	100		130		84	
Cadmium	0		0		1	
Chromium*	0		0		3	
Cobalt	—		0		2	
Copper*	6	-73	27	+285	21	+110
Iron	20		20		20	
Iron (total)*	30	+30	40	+82	40	+60
Lead*	2		0		11	
Manganese*	0		20	+100	20	
Molybdenum	20		55		11	
Nickel	2		7		26	
Silver	0		0		0	
Strontium*	411	+35	490	+45	375	+51
Vanadium	.4		1		1.8	
Zinc*	22		40		40	

*More than 50 percent of the samples analyzed had no interference.
†Using only analyses having no interferences.
‡Changes of greater than 25 percent from 1963-67 median compared to 1968-72 median.

Figure IV-2 **BASIN MAP**

MISSOURI RIVER

SEDIMENT YIELD


CANADA
UNITED STATES
MILK RIVER
FORT PECK RESERVOIR
LAKE SAKAKAWEA
NORTH DAKOTA
MONTANA
YELLOWSTONE RIVER
MISSOURI RIVER
LITTLE MISSOURI RIVER
JEFFERSON R
MADISON R
GALLATIN R
YELLOWSTONE LAKE
WYOMING
POWDER RIVER
SOUTH DAKOTA
CHEYENNE RIVER
LAKE OAHE
LAKE SHARPE
LAKE FRANCIS CASE
JAMES RIVER
BIG SIOUX RIVER
MINNESOTA
LEWIS AND CLARK LAKE
LITTLE SIOUX R
IOWA
NIOBRARA RIVER
NORTH PLATTE RIVER
NEBRASKA
PLATTE RIVER
SOUTH PLATTE RIVER
REPUBLICAN RIVER
SMOKY HILL RIVER
KANSAS RIVER
MISSOURI RIVER
MISSISSIPPI RIVER
OSAGE RIVER
COLORADO
KANSAS
MISSOURI
SCALE 1/11 500 000
100
0
100
200
APPROXIMATE SCALE IN MILES
LEGEND
ESTIMATED SEDIMENT YIELD IN TONS PER SQUARE MILE PER YEAR (DRAINAGES IN EXCESS OF 100 SQUARE MILES)
0-500
500-1000
1000-3000
3000-6000
6000-

Eutrophication Potential. Phosphates are 0.05 to 0.27 mg/l higher at Kansas City than at Gavins Point Dam, indicating significant sources of phosphates in the middle segment of the river. Levels were 0.05 mg/l higher during 1968-72, a period with higher stream flow.

The 1968-72 profile shows the impact of all four urban areas and major tributaries. Phosphate levels are 0.06-0.10 mg/l higher downstream from these points than upstream. The 85th percentiles show a trend toward worsening conditions in the lower 450 miles. Values were 0.5-0.6 mg/l in 1968-72, where in the earlier 5 years they were 0.4-0.5 mg/l. The trend is probably due to the generally higher runoff in the 1968-72 period.

Phosphate levels during the April-June quarter (0.35-0.45 mg/l) are higher than the other three quarters (0.02-0.3 mg/l). The major source is runoff, as indicated by comparing phosphate levels for high- and low-flow conditions. During high flows, the peak stations have phosphate medians between 0.72 and 1.4 mg/l, while during low flows phosphates are at 0.04 mg/l to 0.3 mg/l traveling downstream, interrupted only by dilution from the Kansas River (Figure IV-3).

During 1968-72, ammonia was higher between Omaha and Kansas City than in the upper and lower areas of the river. The highest values are in the segments downstream from large urban areas. For example, between Yankton and Kansas City, ammonia medians are generally between 0.05 and 0.10 mg/l; below Kansas City levels are 0.1-0.3 mg/l. The lower 300 miles of the river show the lowest values, with ammonia being virtually absent in 1968-72.

Differences between quarters for ammonia are more pronounced than for phosphates. The last three quarters (April-December) and low flow periods have similar concentrations: 0-0.1 mg/l from Gavins Point Dam to Kansas City, with peaks below Omaha and St. Joseph; a rise to 0.2 mg/l at Kansas City; and near zero at the lower end of the river. The first three months are significantly higher, with peak medians of 0.3 to 0.48 mg/l; the highest levels, 0.68-0.88 mg/l, occur during high flow in the Omaha and Kansas City Areas (Figure IV-4).

The highest ammonia levels usually occur in March at the Kansas City water intake sampling station. The periodic peaks in the first quarter occur in the transition period immediately after minimum flows, usually in January, and just before major spring runoffs in late March (Figure IV-5).

Nitrates, and nitrites plus nitrates, were not sampled at the same times, so direct comparison of the two parameters is not possible. They are consistent, however, in that both increase threefold between Gavins Point Dam and St. Joseph, Mo. The 85th percentiles at St. Joseph and Kansas City are particularly high (between 1.6 and 1.9 mg/l). Median nitrates levels leaving the Missouri River are 0.7 mg/1, versus 0.9 mg/l below Kansas City.

Salinity, Acidity, and Alkalinity. Compared to levels found in most other rivers, dissolved solids in the middle and lower Missouri River are particularly high, with median values exceeding 500 mg/l below Omaha and the Platte River. Levels are somewhat lower in the area below Kansas City and the Kansas River, as was the case with turbidity. During the 1963-67 period, dissolved solids were higher at all locations than in 1968-72. The largest component of dissolved solids is sulfates, which are at their maximum concentration as water leaves Gavins Point Dam (210 mg/l), then decrease to 135 mg/l at St. Louis. There has been no significant change over the past 10 years.

The 5-year medians for alkalinity, hardness, and pH showed no significant trends in the middle and lower river segments. Alkalinity values range from 158 to 170 mg/l; hardness, 220 to 250 mg/l; and pH, 8 to 8.3, with a drop to 7.6 occurring below Omaha at Nebraska City.

Oxygen Depletion. In the middle segment of the Missouri, median dissolved oxygen levels decrease going downstream, from 11 mg/l near the Gavins Point Dam to 8.5 mg/l near St. Joseph, Mo., with a slight recovery to 9.0 mg/l at Kansas City. In this segment there were no discernible trends over the 10-year period. In the lower segment, dissolved oxygen was generally good medians were 8.1 to 9.5 below Kansas City, and 7.8 to 8.3 mg/l in the last 100 miles.

Figure IV-3 SEASONAL RIVER PROFILES

MISSOURI RIVER

TOTAL PHOSPHATE

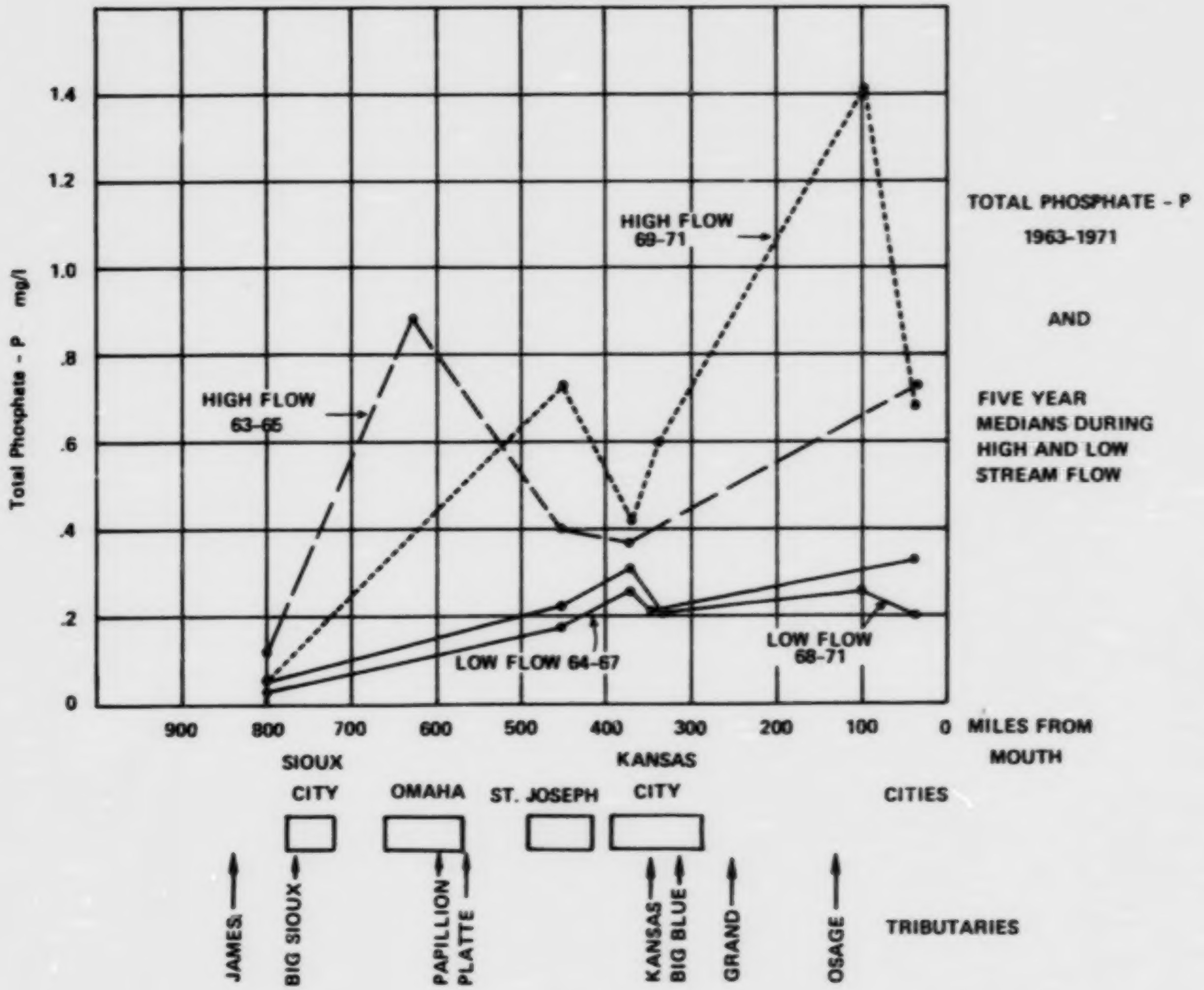


Figure IV-4 **SEASONAL RIVER PROFILES**

MISSOURI RIVER

AMMONIA

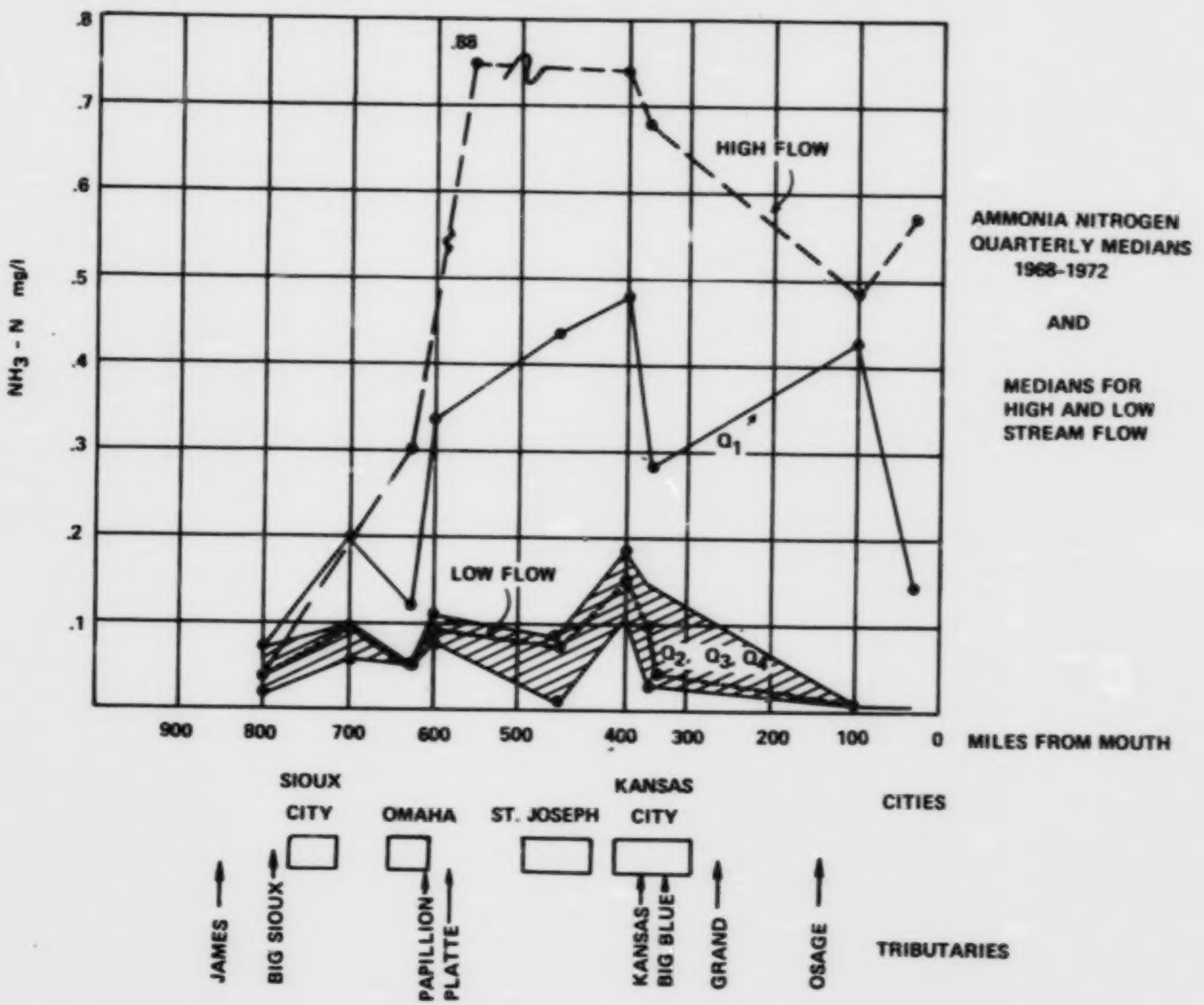
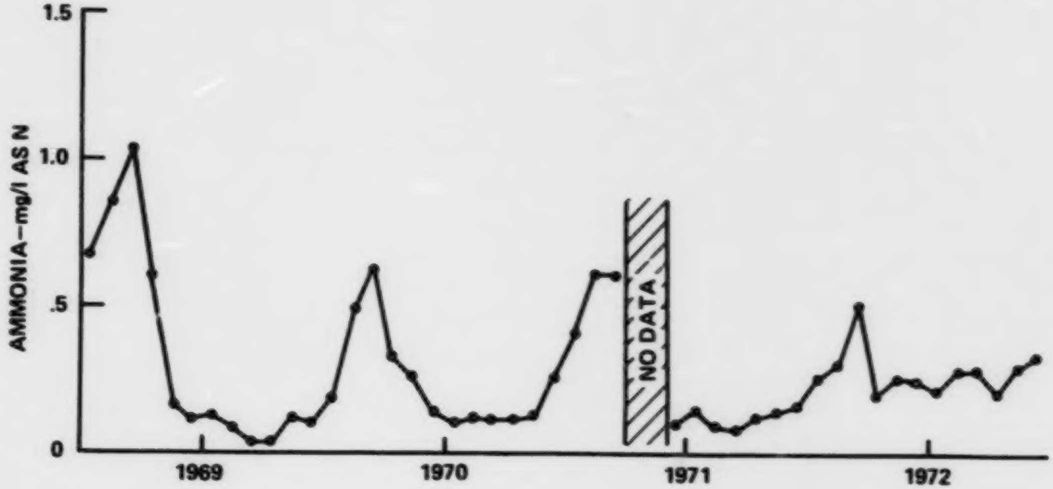


Figure IV-5 TIME TREND AT RIVER MILEPOINT

MISSOURI RIVER

AMMONIA

MONTHLY MEANS FROM DAILY OBSERVATIONS AT KANSAS CITY



The profile pattern for dissolved oxygen saturation is similar to the concentration profile, starting at 95 to 100 percent at Yankton and decreasing to 75 to 85 percent at St. Joseph. The sampling station below Kansas City is the only one that had lower dissolved oxygen saturation (74 percent) in 1968-72, than the earlier 5 years (84 percent).

Quarterly medians for dissolved oxygen over the 10 years are very consistent—second and third quarters are almost always lower than first and fourth quarters. The first and fourth quarters have lower flows and lower temperatures than the second and third quarters. The highest dissolved oxygen values occur in the first quarter, with the entire river above 11 mg/l. The lower levels in the second quarters are due to high runoff, while the lower levels in the third quarter are due to high summer temperatures and low flows (Figure IV-6).

Dissolved oxygen saturation does not show seasonal or flow-dependent changes. Saturation is generally steady for the entire lower 500 miles over the four quarters, with the lowest saturation, 68 percent, occurring below Kansas City in the high-flow second quarter.

Dissolved oxygen measured in periods selected for their unique high and low flow confirms the patterns found in the quarterly data: concentrations were lower during low flow periods, similar to second and third quarter median levels (Figure IV-7).

BOD_5 levels increase from Gavins Point Dam to below Kansas City and the Kansas River for both time periods. The overall increase is twofold, with small decreases between Decatur, Nebr. (below Sioux City) and just above Omaha. A similar decrease occurs between St. Joseph and Kansas City, probably due to the inputs from the Kansas River and the Kansas City metropolitan area. In this segment of the river, BOD_5 median levels were lower in 1969-72 than 1963-67, representing a reduced amount of organic inputs from the St. Joseph and Kansas City areas. The lower 300 miles of the Missouri River did not have enough sampling stations for meaningful analysis.

Seasonally, the highest BOD_5 levels, 4 to 6 mg/l, occur during January-March, with the third and fourth quarters being very similar, 1 to 2 mg/l; below Kansas City, however, the level is about 3 mg/l. The high levels in the first quarter and somewhat lower levels in the second quarter indicate the significance of runoff from late February through May. In all quarters, BOD_5 peaks occur below cities and tributaries, with the third and fourth quarters indicating the inputs from point sources. As with dissolved oxygen, BOD_5 measured during unique high and low flow conditions confirms the general patterns found in the quarterly data, with the only difference being higher high-flow medians, 4 to 6 mg/l, below Kansas City and at the mouth, where the corresponding first and second quarter levels are 3 to 4 mg/l (Figure IV-8).

The high BOD_5 levels in the winter and spring do not significantly depress the dissolved oxygen but do keep the level on the lower river generally 5 mg/l lower than the upstream clean waters at Yankton.

For the three stations reporting at Omaha, Kansas City, and St. Louis, COD levels are 3 mg/l higher at Kansas City than at Omaha, (18 to 20 mg/l), but 10 mg/l lower at St. Louis than at Kansas City. Median levels showed about a 10 percent improvement in the past 5 years.

While the various analyses indicate that dissolved oxygen levels are generally high in the river, depressed dissolved oxygen levels have occured, as attested to by three documented fish kills:

- *May 24, 1964.* In the 130-mile stretch between Leavenworth, Kans., and Easely, 280,000 fish were killed. Dead fish were found as late as May 28 from the Iowa line to Easely, downstream 384 miles.[1]
- *May 23, 1966.* A moderate kill over a distance of 20 miles between Brownville and Rulo, Nebr.[1]

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[1] Annual reports, *Fish Kills Caused by Pollution*, Federal Water Pollution Control Agency (FWPCA), 1964 and 1966.

Figure IV-6 SEASONAL RIVER PROFILES

MISSOURI RIVER

DISSOLVED OXYGEN

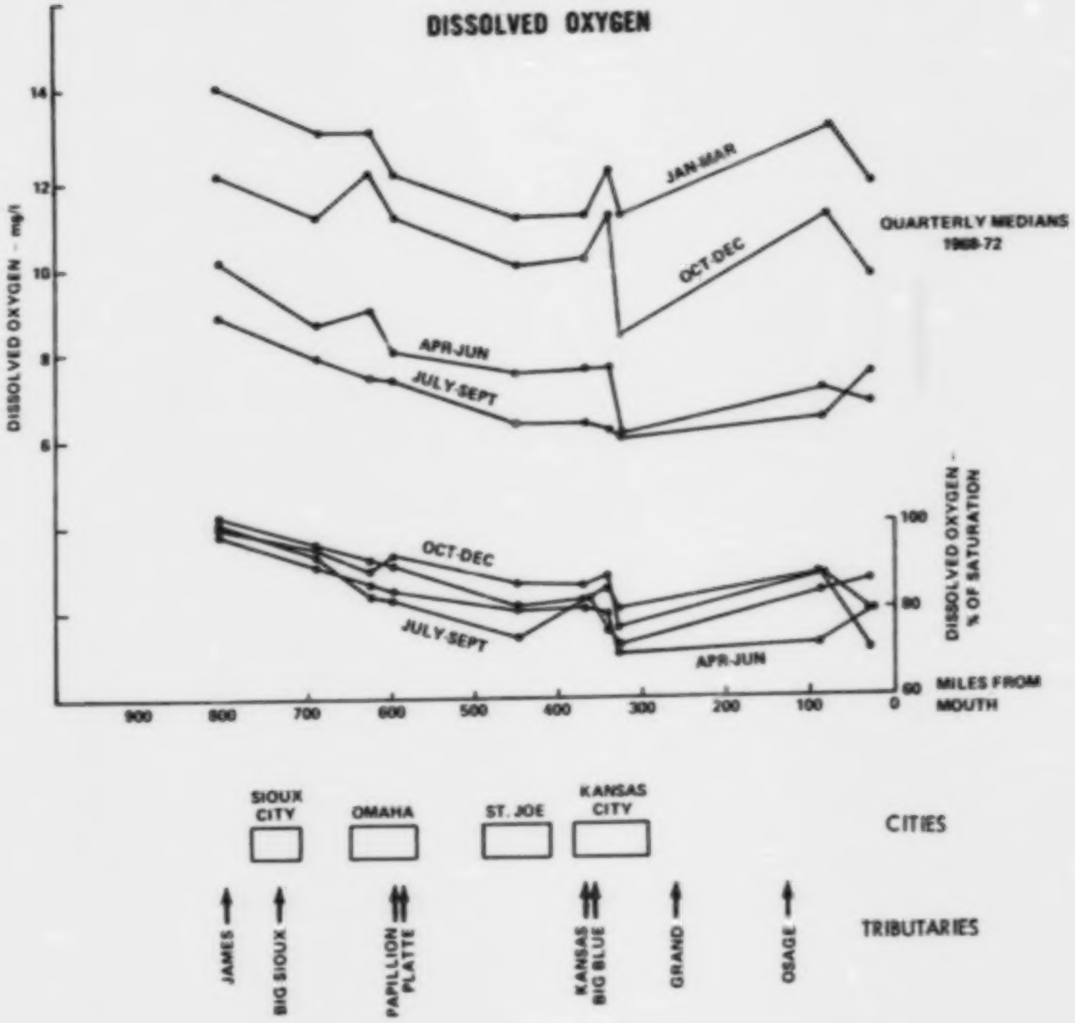


Figure IV-7 RIVER PROFILES

MISSOURI RIVER

DISSOLVED OXYGEN

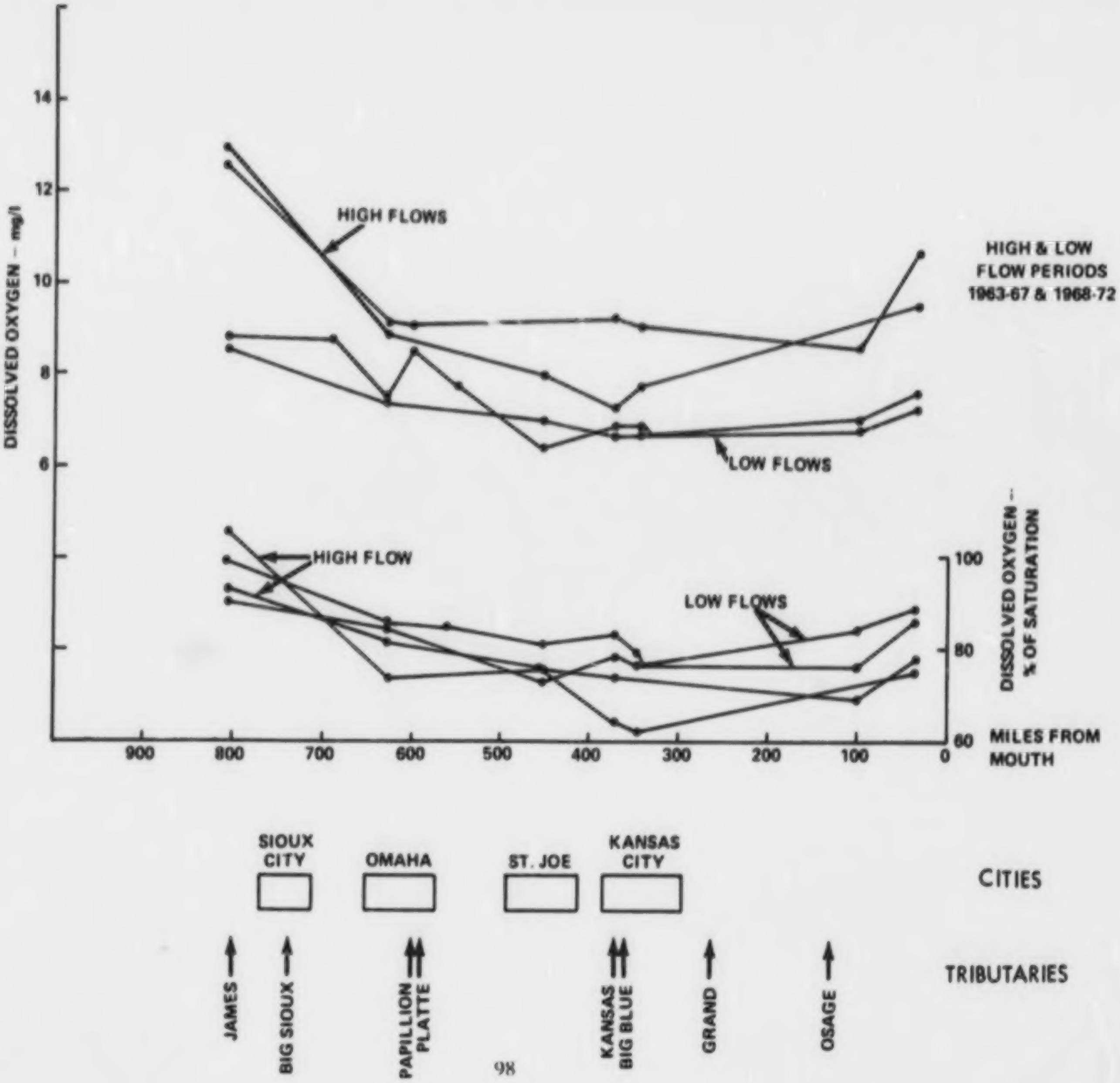
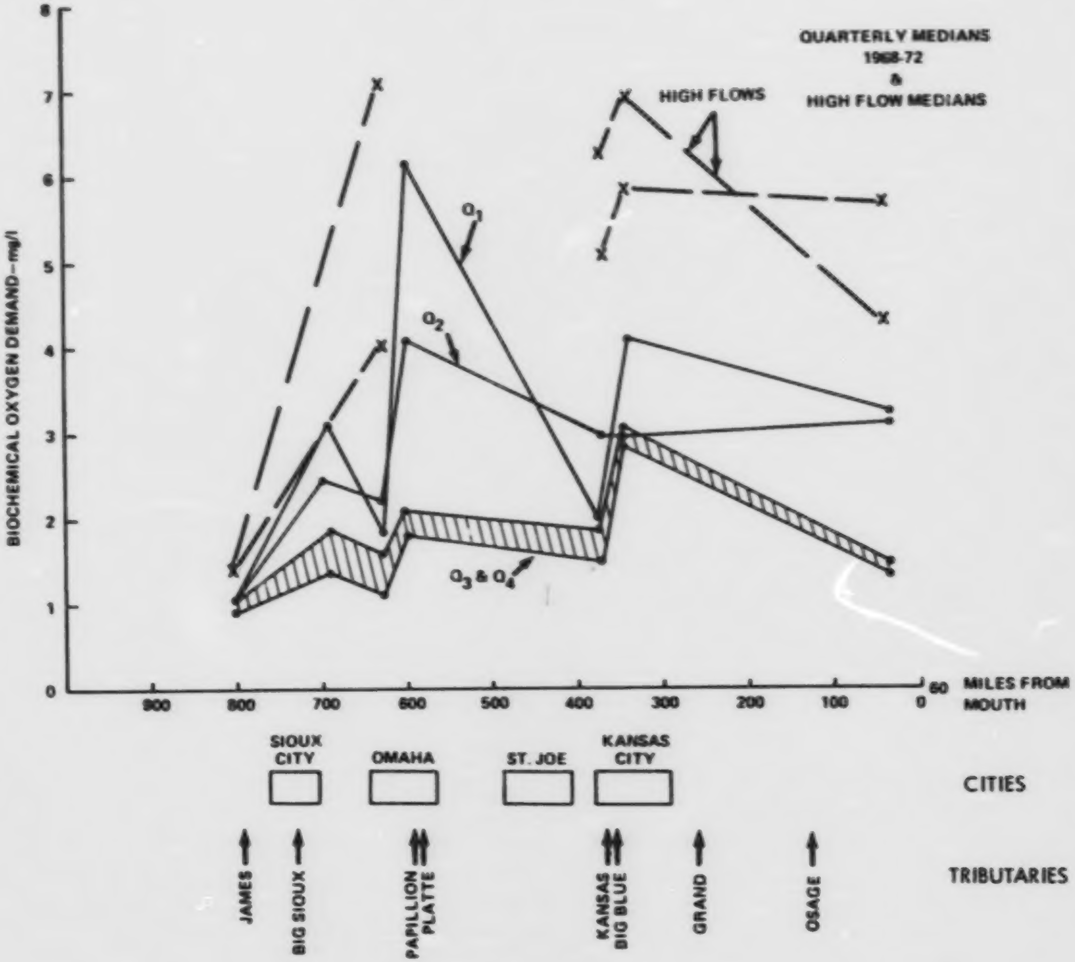


Figure IV-8 **RIVER PROFILES**

MISSOURI RIVER

BIOCHEMICAL OXYGEN DEMAND



- *June-July, 1967.* Surveys during and after a fish kill between St. Joseph and Jefferson City, Mo., showed that stream flow varied between 80,000 and 260,000 cfs at Kansas City; dissolved oxygen was virtually zero, remained less than 4 mg/l for 7 days, and did not reach 5 mg/l for 15 days at St. Joseph. Dissolved oxygen dropped and remained less than 5.0 mg/l to 2.1 mg/l for almost a month 313 miles downstream at Jefferson City.[2]

Routine water quality data taken at the same time as the 1967 kill did not detect the zero dissolved oxygen mentioned in the fish kill report, but did show fluctuating levels during the peak flows and some increases in BOD_5 and COD (Table IV-8).

TABLE IV-8

MISSOURI RIVER FISH KILL (June-July 1967)*

Location	Date (1967)	Flow (cfs)	Dissolved oxygen (mg/l)	Dissolved oxygen saturation (%)	BOD_5 (mg/l)	COD (mg/l)
Omaha	5/22	33,200	9.2	92	2.3	22
	5/29	34,900	8.4	87	2.4	20
	6/5	34,900	6.0	64	6.2	46
	6/12	44,000	7.5	83	6.5	230
	6/19	40,800	3.9	44	7.5	210
	6/26	39,100	6.9	75	6.5	60
	7/3	31,500	6.0	69	1.5	28
	7/10	34,000	4.5	53	1.5	40
	7/17	35,800	6.9	82	1.5	34
	7/24	35,800	6.4	78	2.2	30
	7/31	35,500	6.6	80	1.6	16
Kansas City	5/23	36,320	8.7	93	2.7	20
	5/29	37,900	7.4	–	2.4	19
	6/13	147,000	3.3	37	2.7	178
	6/20	157,700	4.4	52	2.2	71
	6/27	94,300	4.9	55	2.6	128
	7/3	58,400	5.5	65	1.7	67
	7/11	49,200	6.1	71	2.8	23
	7/25	42,900	6.3	79	2.1	26
	8/1	43,100	5.7	70	1.4	35
	8/15	39,680	6.7	78	1.4	21

*Routine data from STORET.

Health Hazards and Aesthetic Degradation. Median coliform counts of over 10,000/100 ml exceed standards throughout the entire lower 700 miles of the river except at Gavins Point Dam (less than 100/100 ml). Total coliforms decrease significantly at Kansas City, dropping from 170,000/100 ml in 1963-67 to 48,000 in 1968-69; lesser improvements occur at the St. Joseph and Kansas City water intakes and in the St. Louis area. The upper river remained unchanged over 1963-69. There were no fecal coliform data prior to 1968 to observe any changes. The peak condition for fecal coliforms is in the Omaha area (over 20,000/100 ml), whereas the peaks for total coliform are in the St. Joseph and Kansas City areas.

The preceding discussion was based on routine data available in STORET. With the exception of bacteriological measurements (total and fecal coliforms), the data showed few problems near urban areas, possibly because of the distance of sampling points from waste sources. Special studies along the main stem pinpoint the impairment of water quality and stream biota in urban areas and serve to highlight the significance of point sources discharges.

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[2] *Second Compendium of Animal Waste Management*. FWPCA. Kansas City, Mo. June 1969.

Special fecal sterol and virus isolation investigations specifically indicated the presence of domestic discharges. The results showed high levels in the river below urban areas (Table IV-9). The values are particularly significant because of the dilution waste waters receive upon entering the river, and because, in 73 percent of the cases, the samples were collected during steady state streamflow conditions–that is, no peak flows in the proceeding 6 to 10 days, indicating minimal runoff. The potential hazards from fecal pollutants were further noted from the special virus isolation study, which found viruses present below urban areas and at water supply intakes; upstream from Sioux City, none were found. Samples collected during this study were also essentially during steady state flows (75 percent).

The impact of point source discharges were further measured by fish and stream bottom studies (Figure IV-9). On the 440-mile reach of Missouri River (RM 735 to 293) studied, unacceptable flesh flavors were found in fish placed at locations bracketing a total of 26 miles of river, all of which were confined to metropolitan areas. Wastes discharged from the Kansas City area were found to be toxic to fish. Bottom animals found over 638 miles of the river show that 279 miles were unpolluted and 107 miles were grossly polluted from organic matter. The polluted miles were generally near or downstream from metropolitan areas, with the lower 270 miles recovering slightly.

TABLE IV-9

MISSOURI RIVER MAIN STEM: FECAL POLLUTION DATA

	1971-72	January-May 1970		October 1969-April 1970	
				Virus recovered (PFU/Sample)†	
River miles from mouth	Fecal coliform (no./100 ml)*	Fecal coliform (no./100 ml)	Coprostanol (micrograms per liter)	Water	Silt
85	4				
736		140	6		
732.72				0	0
717.4		13,000	101	1	3
691	3,100				
626.2		770-1,000	20-21		
601.7	23,000	4,200	72	4	6
559.7		3,800	70		
452.3	1,300-3,800	2,100-1,800	33	3 to 19	0
440.3		2,800	49	1 to 3	0
370.5		3,150-5,500	56-82		
345.4	10,000	6,100	87		
336	10,000				
293		4,000	70		
98	4,400				
36	930				

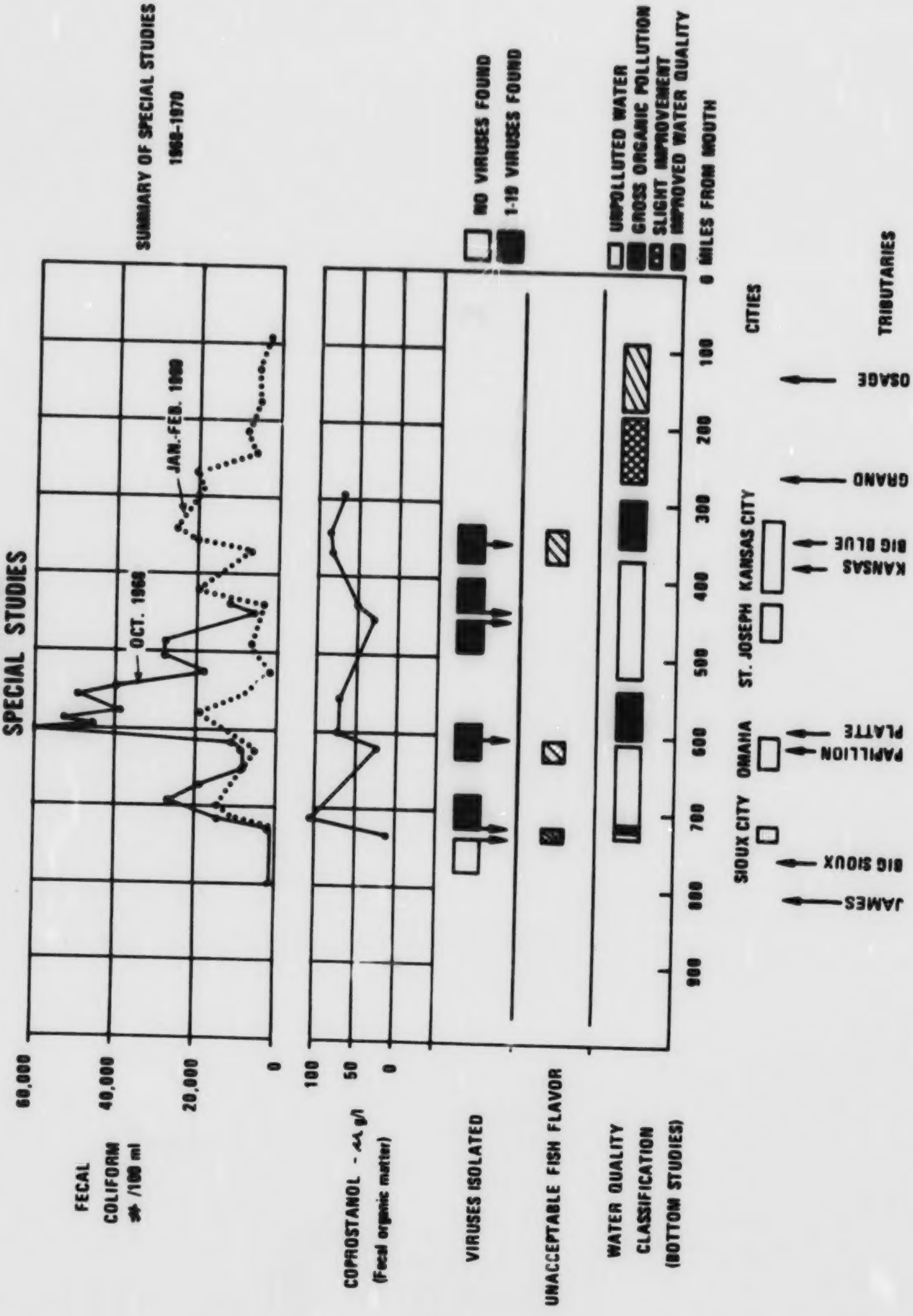
*Routine data from STORET.

†Plaque-forming units.

Figure IV-9 **RIVER PROFILES**

MISSOURI RIVER

SPECIAL STUDIES



V. OHIO RIVER

Chemical and physical data indicate several pollution problems in the Ohio River. One is low alkalinity arising from drainage from mines located on tributaries to the Ohio; a second is high total and fecal coliform levels downstream from municipal sewage treatment plants. A third is increasingly high iron and manganese concentrations. In addition, biological studies show the presence of toxic materials downstream from Pittsburgh. From 1963-67 to 1968-72, the most noticeable trends in Ohio River pollution were increased concentrations of iron, manganese, DDT, and chlordane.

The key pollutants show the following trends:

- *Harmful Substances.* Monitoring data show high levels of iron and manganese throughout the river, with upward trends in the past 5 years. Special studies show industrial oil, scum, foam, phenols, and other chemicals affecting areas near Pittsburgh, Huntington, Marietta, and Parkersburg. Biological studies confirm the presence of toxic materials near Pittsburgh. Downstream the river shows recovery, and some improvements have been noted since 1970.

- *Physical Modification.* High levels of suspended solids occur in the lower Ohio, primarily during high flows. Lower, but still undesirable, peaks occur near heavily-settled areas around Wheeling, Huntington, and Cincinnati. In some portions of the river, the levels are markedly improved compared to what they were 5 to 10 years ago.

- *Eutrophication Potential.* Indirect evidence suggests that biological activity is heightened in the summer, but no undesirable algal growths have been reported. Nitrates and phosphates are high enough to support undesirable growths, but other factors (such as turbidity) are inhibiting growth. Point sources appear to be responsible for most of the dissolved phosphorus in the river. Total phosphorus, however, consists primarily of the insoluble forms, and is higher during high flow than low flow.

- *Salinity, Acidity, and Alkalinity.* The river violates acidity standards at 11 of 40 stations, for at least 15 percent of observations. Acid mine drainage to upstream tributaries, as well as acidic industrial discharges, lowers the buffering capacity of the river (alkalinity) compared to that of nearby rivers. Chlorides are higher at low flow than at high flow, particularly downstream from the Muskingum River, indicating the presence of point sources on that tributary.

- *Oxygen Depletion.* Pittsburgh and Cincinnati municipal discharges are known to be causing low dissolved oxygen at times, but the condition is not widespread.

- *Health Hazards and Aesthetic Degradation.* Coliform levels are extremely high along the river, with peaks at high density population centers. The most bacteriologically polluted area is at Cane Run, downstream from the Louisville sewage treatment plant, where median summertime concentrations of total coliforms reach 650,000 per 100 ml and fecal coliforms reach 47,000 per 100 ml. Total and fecal coliforms in the summer are also excessively high at Cincinnati. Local studies show that bacterial levels improved near other cities in the past 5 years. Field studies indicate that if industries and municipalities adhere to effluent limitations, the Ohio will meet standards for fish and (in some areas) for swimming by 1977. However, nutrients and sediment runoff may continue to be a problem, since runoff sources, which are not subject to direct controls, are producing significant levels of nutrients and sediment.

GENERAL PHYSICAL DESCRIPTION

The headwaters of the Ohio River are principally in western Pennsylvania and in West Virginia. The river is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, and flows southwesterly for 981 miles to its confluence with the Mississippi River at Cairo, Ill. The total length of the Ohio-Allegheny River system is 1,306 miles, making it the eighth longest in the United States. The river drains approximately 203,000 square miles and develops an annual average streamflow of 263,000 cfs, the second highest in the United States (Table V-1).

The major urban centers along the river are Paducah, Covington, Newport, Owensboro, Louisville, and Ashland, all in Kentucky; Evansville, Ind.; Cincinnati, Portsmouth, Ironton, Marietta, and Steubenville, all in Ohio; Huntington, Parkersburg, Weirton, and Wheeling, all in West Virginia; and Pittsburgh, Pa. (Figure V-1).

There are 35 dams on the river, forming pools with depths ranging from 9 to 50 feet. The dams are used to assure a navigation depth of at least 9 feet, and at times of extremely low flow the stream velocity also is very low. Upstream from Louisville, most of the old, low-head wicket dams have been replaced by higher-head structures, creating longer, deeper pools with lower velocities. These modifications tend to depress dissolved oxygen at low flows by reducing the capacity of the water to assimilate BOD. As older dams below Louisville are replaced by higher-head dams, the effects produced above Louisville should propagate downstream.

Normal monthly rainfalls at several cities along the river are generally highest from January through June, leveling off from April until June and decreasing from June until October (Figure V-2). The monthly pattern of streamflows during 1963-72 at points along the river follow the same general pattern as rainfall each year (Figure V-3). Only small amounts of water are apparently being impounded by the dams, since the streamflow pattern does not lag behind the rainfall pattern.

The period 1968-72 was much wetter than 1963-67, complicating the interpretation of trends over the past decade (Figure V-4). Some runoff-related pollutants might tend to have higher concentrations in 1968-72 simply because there was more rainfall, not because of worsening pollution. This factor has been taken into account in the analysis of trends in the Ohio River.

TABLE V-1

OHIO RIVER DRAINAGE AREAS AND FLOWS*

Location (river miles from mouth)	Cumulative drainage area	Daily flows		
		Annual avg	Max	Min
	(square miles)	(cubic feet per second)		
Sewickley, Pa. (969.2)	19,500	32,900	574,000	1,800
Parkersburg, W. Va. (796.6)	35,600	50,880	440,000	2,290
Huntington, W. Va. (669.4)	55,900	77,580	654,000	3,200
Cincinnati, Ohio (510.5)	76,580	96,560	894,000	NA
Louisville, Ky. (373.7)	91,170	113,700	1,110,000	4,090
Evansville, Ind. (188.7)	107,000	133,500	1,410,000	NA
Metropolis, Ill. (37.0)	203,000	262,800	1,780,000	20,600

*Source: *The Water Encyclopedia*, Water Information Center, 1970. Data from U.S. Geological Survey as of 1960.

Figure V-1 AREA MAP

OHIO RIVER

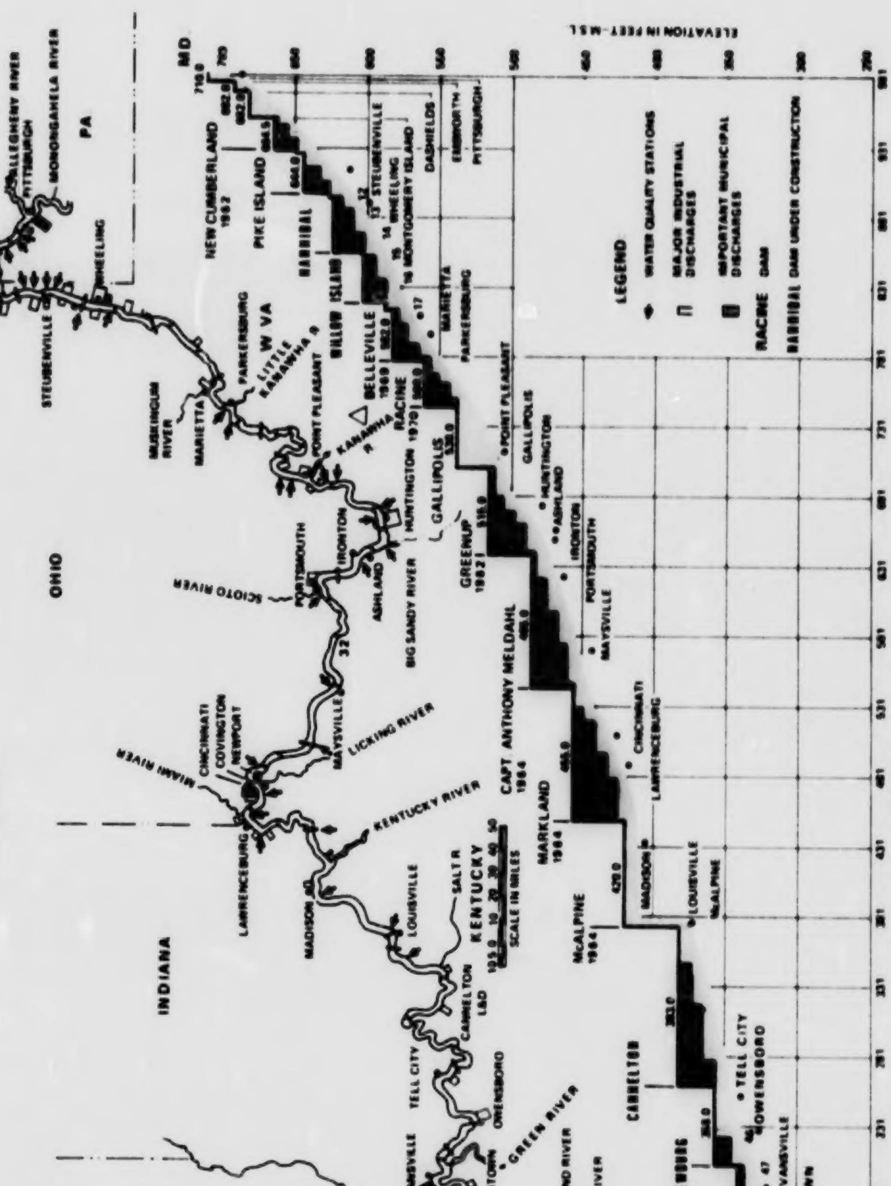

ILLINOIS
INDIANA
OHIO
KENTUCKY
W VA
PA
MD
MISSOURI
MISSISSIPPI RIVER
WABASH RIVER
GREEN RIVER
CUMBERLAND RIVER
TENNESSEE RIVER
KENTUCKY RIVER
SALT R
LICKING RIVER
MIAMI RIVER
SCIOTO RIVER
BIG SANDY RIVER
KANAWHA R
LITTLE KANAWHA R
MUSKINGUM RIVER
ALLEGHENY RIVER
MONONGAHELA RIVER
CAIRO
PADUCAH
METROPOLIS
EVANSVILLE
OWENSBORO
TELL CITY
LOUISVILLE
MADISON
LAWRENCEBURG
CINCINNATI
COVINGTON
NEWPORT
MAYSVILLE
PORTSMOUTH
IRONTON
ASHLAND
HUNTINGTON
POINT PLEASANT
PARKERSBURG
MARIETTA
WHEELING
STEUBENVILLE
PITTSBURGH
UNIONTOWN L&D
CANNELTON L&D
SCALE IN MILES
10 0 10 20 30 40 50
SMITHLAND
UNIONTOWN
NEWBURG
CANNELTON
McALPINE 1964
MARKLAND 1964
CAPT. ANTHONY MELDAHL 1964
GREENUP 1962
GALLIPOLIS
RACINE 1970
BELLEVILLE 1969
WILLOW ISLAND
HANNIBAL
PIKE ISLAND
NEW CUMBERLAND 1962
DASHIELDS
EMSWORTH
MONTGOMERY ISLAND
LEGEND
WATER QUALITY STATIONS
MAJOR INDUSTRIAL DISCHARGES
IMPORTANT MUNICIPAL DISCHARGES
RACINE DAM
HANNIBAL DAM UNDER CONSTRUCTION
ELEVATION IN FEET - M.S.L.
RIVER MILES

Figure V-2. **TIME TRENDS AT RIVER MILEPOINTS**

OHIO RIVER

MONTHLY RAINFALL

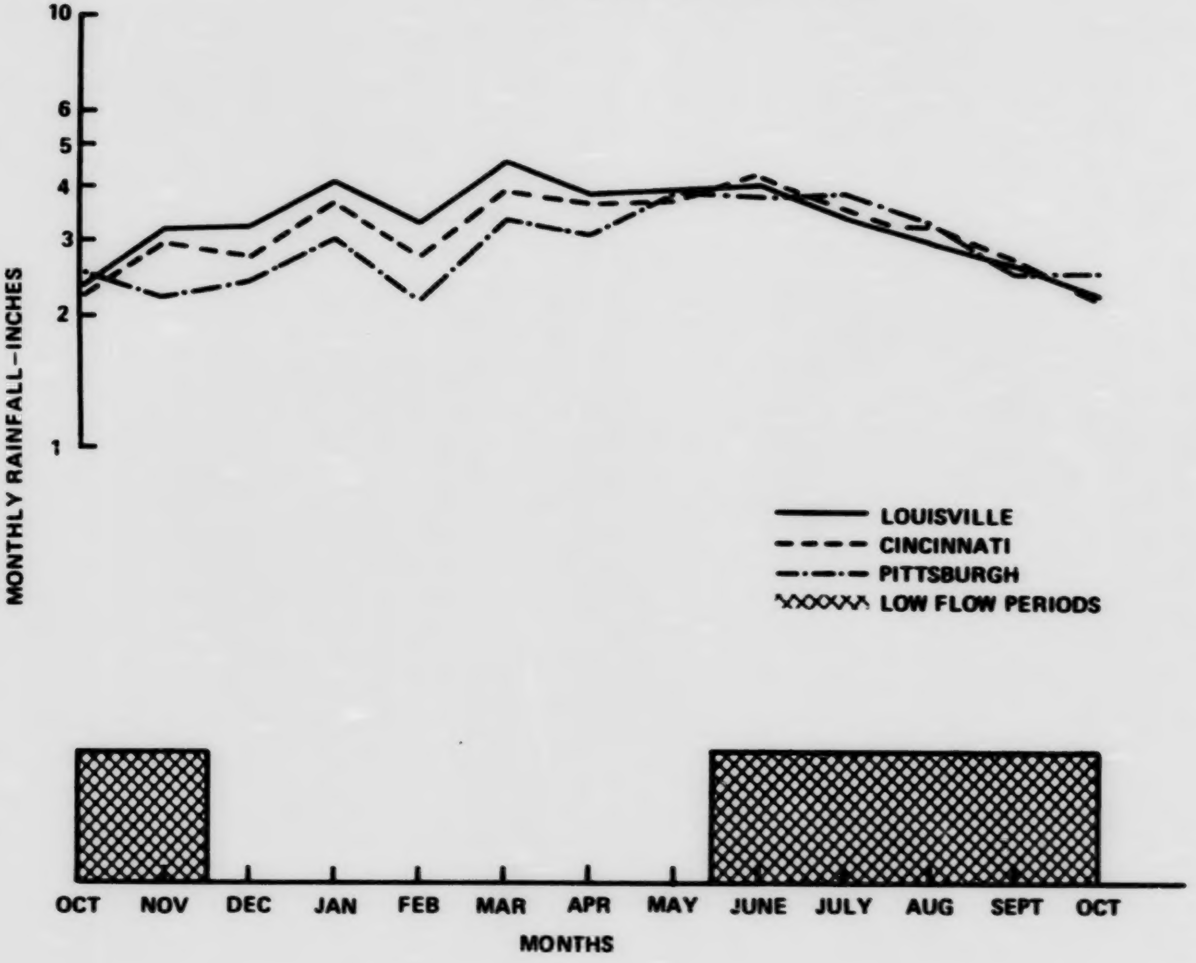


Figure V-3. TIME TRENDS AT RIVER MILEPOINTS
OHIO RIVER
MONTHLY MEAN DISCHARGE

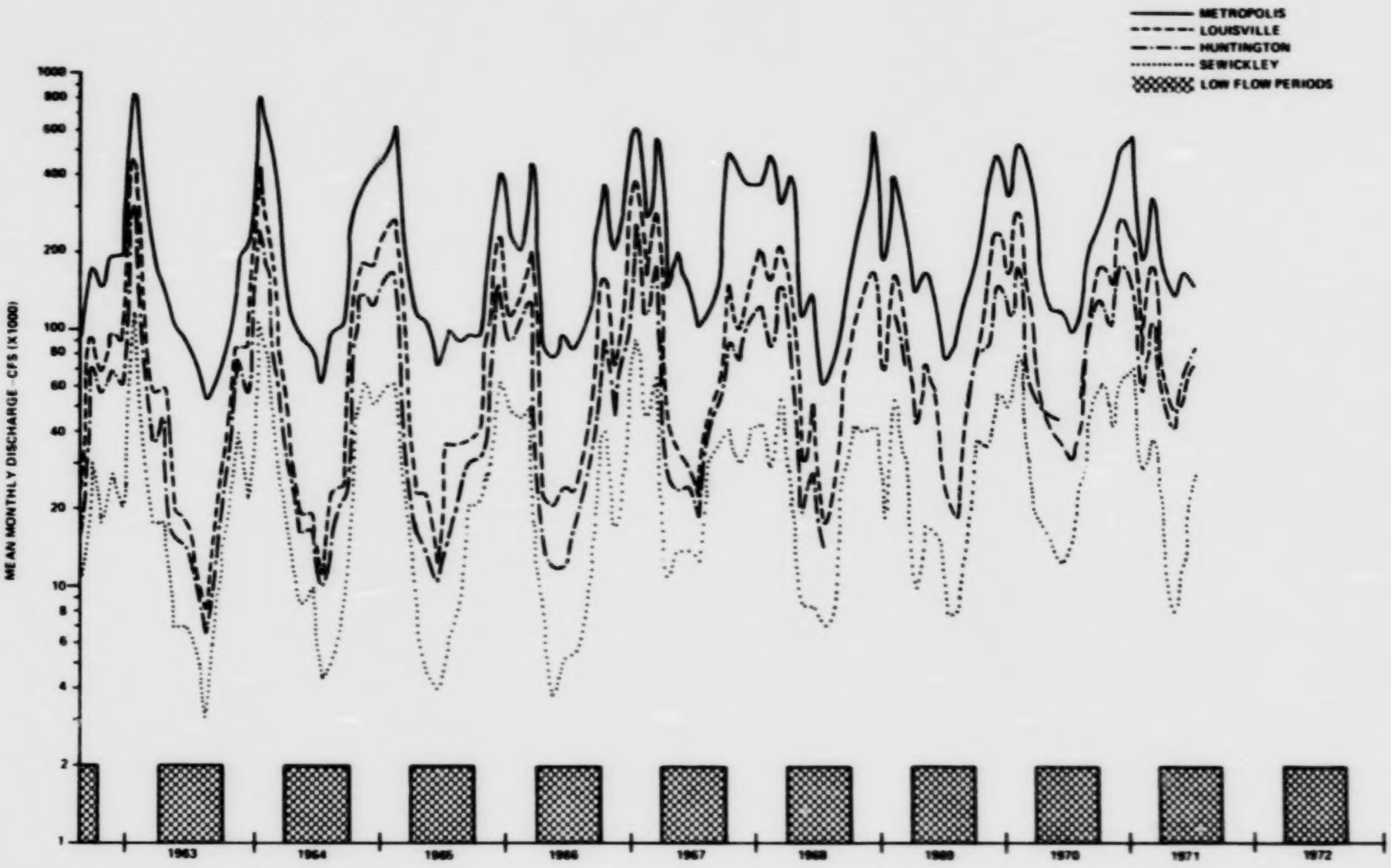
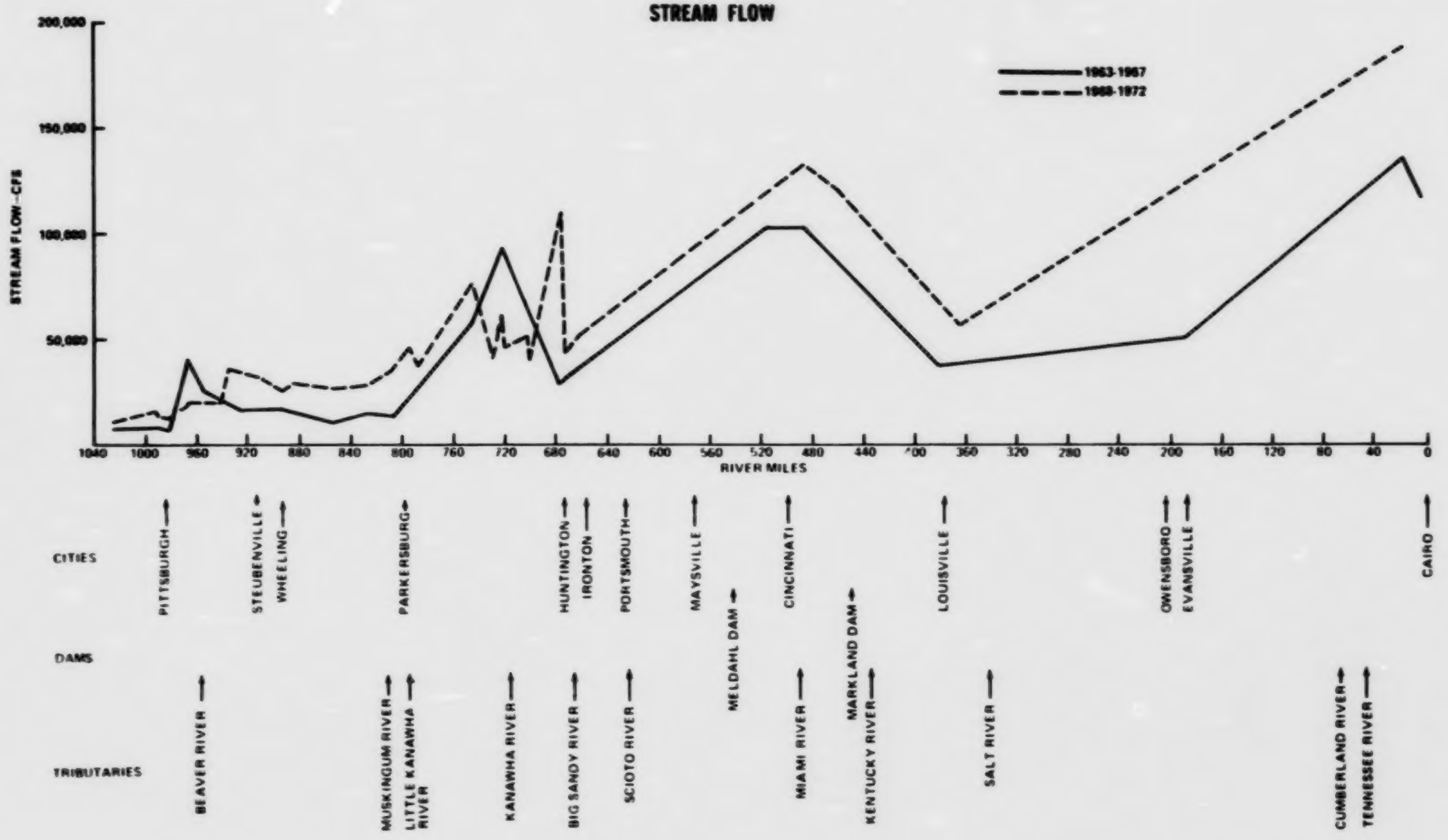


Figure V-4 RIVER PROFILES

OHIO RIVER

STREAM FLOW



DATA AND METHOD

The analysis covered 53 STORET water quality stations at 50 sites. Of the 53 stations, nine were operated by the U.S. Geological Survey, 25 by EPA, 10 by other Federal agencies, eight by West Virginia, and one by Indiana. Some stations are part of the cooperative sampling network run by the Ohio River Valley Water Sanitation Commission (ORSANCO).

The data were aggregated into three-month groups with similar flow and temperatures–December-February as the first group, followed by March-May, June-August, and September-November. The first two quarters (winter and spring) have low temperatures and high flows; the other two quarters (summer and fall) have high temperatures and low flows.

WATER QUALITY CONDITIONS

Harmful Substances

For the analysis of metals and pesticides, the river was divided into four segments: Pittsburgh to Marietta, Marietta to Portsmouth, Portsmouth to Brandenburg, and Brandenburg to Cairo.

Iron and manganese are the only metals with enough data available for determining status and trends (Table V-2). Upstream in the Pittsburgh-Marietta segment, median dissolved manganese levels are high (460 to 500 μg/l, depending on season), well above the Public Health Service standard of 50 μg/l for drinking water. The levels decrease moving downstream, but are still high near the mouth at Cairo (75 to 90 μg/l). Dissolved iron follows a similar pattern–high upstream (390-1,400 μg/l), falling off moving downstream (to 34-36 μg/l), but rising sharply near the mouth (510 to 1,800 μg/l). The Public Health Service standard for dissolved iron is 300 μg/l. Both metals have high extreme values, as shown by the 85th percentile levels. In all four segments of the river, both iron and manganese increased from 1963-67 to 1968-72.

TABLE V-2

OHIO RIVER METALS CONCENTRATIONS (1968-72)

Segment	Manganese		Iron	
	Winter	Summer	Winter	Summer
		(micrograms/liter)		
		(median values)		
Pittsburgh-Marietta	500	460	1,400	390
Marietta-Portsmouth	320	170	600	180
Portsmouth-Brandenburg	86	60	34	36
Brandenburg-Cairo	90	75	1,800	510
		(85th percentile values)		
Pittsburgh-Marietta	700	800	3,200	1,200
Marietta-Portsmouth	600	460	1,700	460
Portsmouth-Brandenburg	360	150	675	104
Brandenburg-Cairo	330	150	5,400	1,600

The only segment with sufficient pesticide data for this analysis was the Brandenburg to Portsmouth segment, which includes the Cincinnati and Louisville areas. In this segment, DDT and chlordane concentrations have increased, while BHC and dieldrin concentrations have decreased (Table V-3). Levels are generally higher in winter (when flows are high) than in summer, suggesting that pesticides originate in the runoff from agricultural operations. Part of the increase in the DDT and chlordane concentrations was probably caused by higher flows in 1968-72 compared to 1963-67.

Physical Modification

Suspended Solids. Natural sources, point sources, and nonpoint sources appear to be producing moderately high levels of suspended solids in the Ohio, especially in the middle and lower river. Suspended solids from stream bed scouring, erosion, and agricultural runoff are causing concentrations to be higher and more variable during the months of high streamflow (December-May) than in low-flow months (June-November). The average station's extreme values in winter (high flow) are 2.7 times its summer (low flow) values (Table V-4). Localized sources, such as industries and urban areas, also affect the levels of suspended solids in the river, resulting in local peaks downstream from the Wheeling, Huntington, and Cincinnati areas (Figure V-5). Concentrations also rise somewhat downstream from Louisville, owing to the higher velocities of the river in this area of low-head dams.

Median solids levels at four equidistant stations on the Ohio range from very low (8 to 48 mg/1) in the dryer summer months, to moderately high in the wet winter months (53 to 165 mg/1) (Table V-5).

While the data for 1963-67 are not as complete as they should be for trend analysis, there are enough to show that in the upper river (Pittsburgh to Huntington), suspended solids decreased markedly from 1963-67 to 1968-72 (Figure V-6). In this portion of the river, the earlier data clustered around 280 mg/l, while the later data clustered around 20 mg/l, despite generally higher flows in the later period. The trend is not conclusive, however, because the 1963-67 data occur almost entirely at stations for which there are no 1968-72 data; furthermore, at stations measured in both periods, levels are increasing, not decreasing. This suggests that solids concentrations might not have really improved. However, recent enforcement actions aimed at controlling solids and other pollutants, as well as new high-head dams, probably account for some reductions.

Temperature. While installation of dams has undoubtedly caused many changes in the natural temperature regime of the river, the available data show no discernible trends or unusual variations in temperature on the river.

TABLE V-3

OHIO RIVER PESTICIDE CONCENTRATIONS, BRANDENBURG TO PORTSMOUTH (1963-72)

	1963-67		1968-72	
Pesticide	Winter (6 samples)	Summer (6-13 samples)	Winter (25 samples)	Summer (23 samples)
		(parts per billion)		
DDT	0.04	0	0.11	0.01
BHC	0.01	0.013	0.005	0.005
Chlordane	0	0	0.01	0.01
Dieldrin	0.01	0.006	0.005	0.005

Figure V-5 SEASONAL RIVER PROFILES

OHIO RIVER

TOTAL SUSPENDED SOLIDS

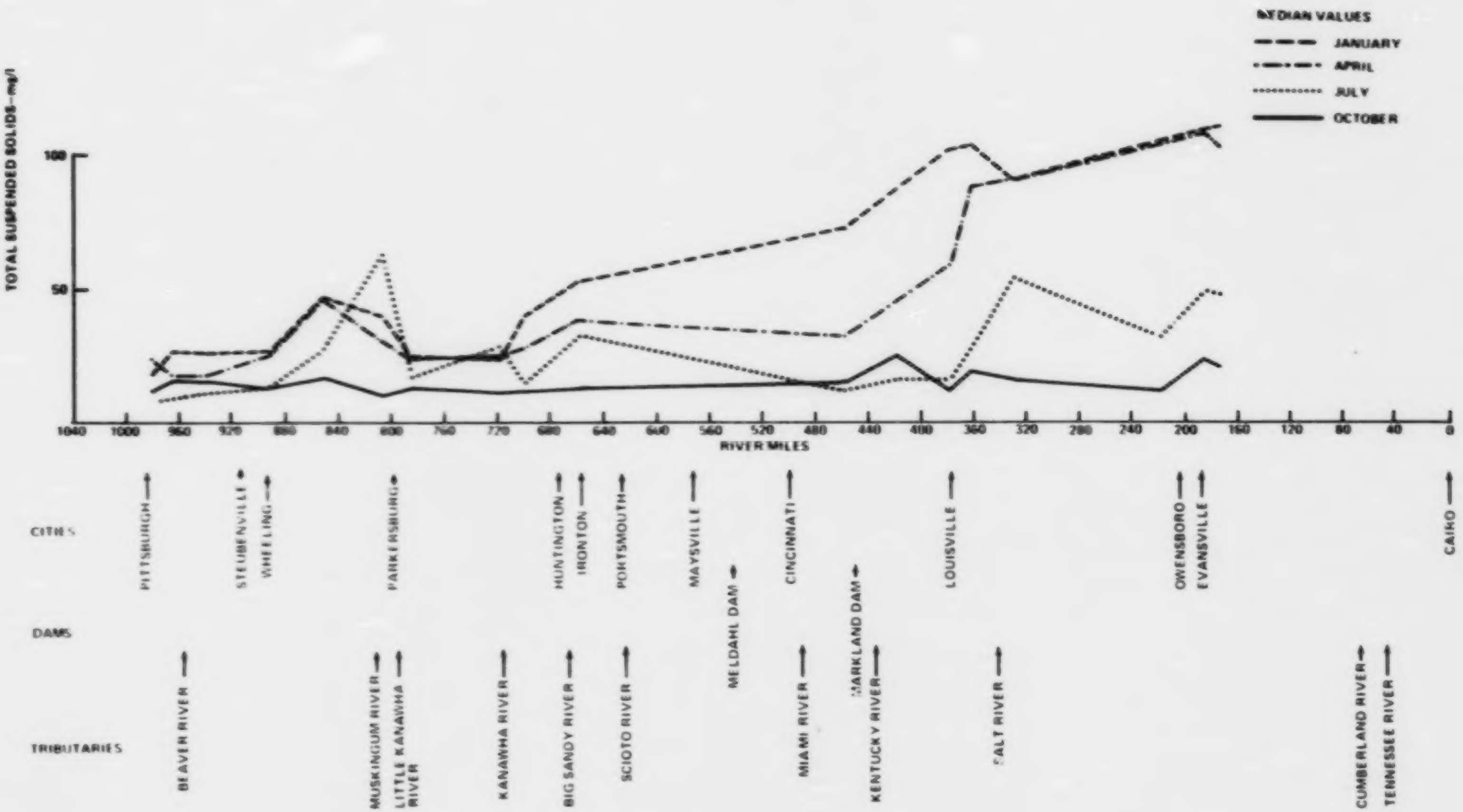


Figure V-6 RIVER PROFILES

OHIO RIVER

TOTAL SUSPENDED SOLIDS

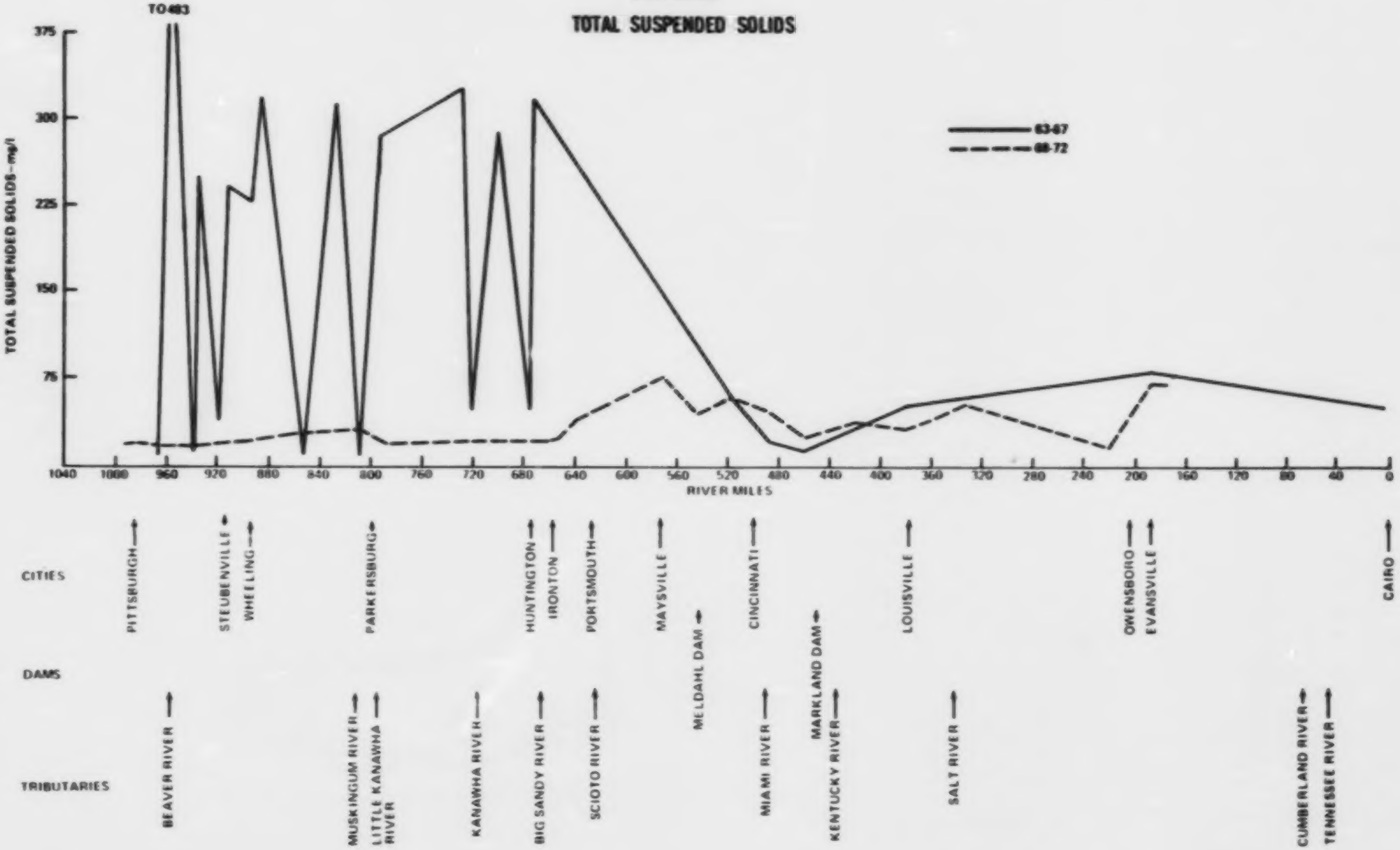


TABLE V-4

OHIO RIVER ANALYSES BY SEASON (1968-72)*

Analysis	85th Percentile		Winter/summer
	Winter	Summer	ratio
	(mg/l unless shown)		
Dissolved iron	2.74	0.84	3.2
Suspended solids	163	60	2.7
Ammonia nitrogen	1.23	0.6	2.0
Total phosphorus	0.29	.15	1.9
Dissolved manganese	0.50	0.39	1.3
Total alkalinity	2[illegible]†	33.5†	1.2‡
BOD_5	3.7	3.0	1.2
Organic nitrogen plus ammonia (as N)	3.2	2.6	1.2
pH (Standard units)	6.7†-7.3	6.8†-7.4	1.0‡-1.0
Oxygen saturation (%)	77.7†	70.1†	0.9‡
Dissolved solids	214	264	0.8
Chlorides	34	43	0.8
Nitrate plus nitrite (as N)	1.35	1.72	0.8
Dissolved phosphorus (as P)	0.05	0.07	0.7
Conductivity (μmhos)	383	530	0.7
Dissolved oxygen	9.7†	5.9†	0.6‡
Total coliforms (no./100 ml)	87,800	238,00	0.4
Fecal coliforms (no./100 ml)	3,000	18,000	0.2

*Based on values that were exceeded by 15 percent of samples during 1968-72 at average station on the Ohio River. Pollutants listed according to winter-to-summer ratios: those near the top tend to arise from scour or runoff effects; those near the bottom may be more closely identified with point sources.

†15th Percentile concentrations.

‡Summer/winter ratio.

Eutrophication Potential

No nuisance algal growths have been reported on the Ohio, probably because of natural inhibiting factors. However, chemical tests for nitrogen and phosphorus show that in-stream nutrients are available for algae and provide evidence of biological activity.

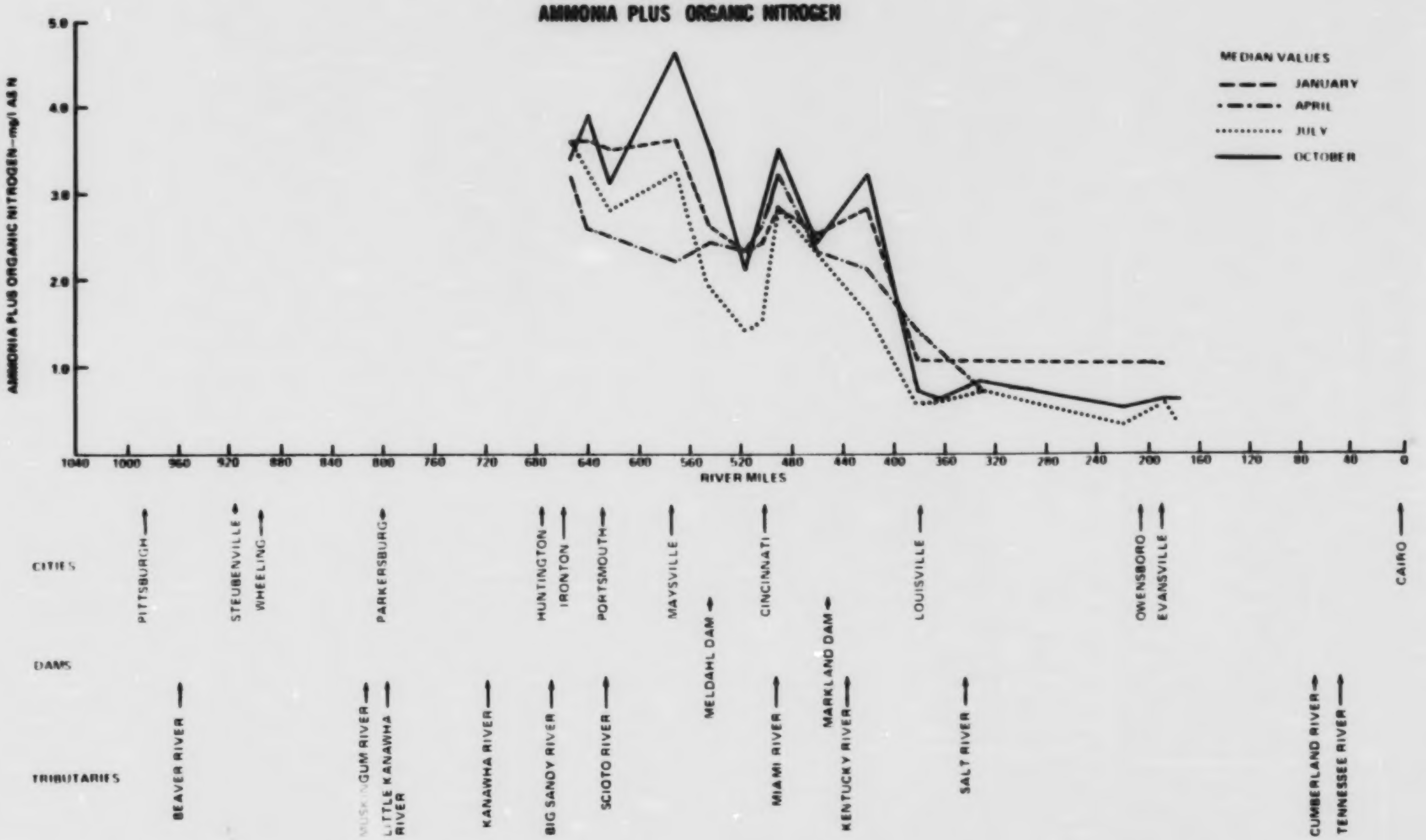
The data for organic nitrogen plus ammonia show that the highest levels are found in the upper and middle portion of the river above Markland Dam (RM 450) and Louisville. This indicates that biological activity is higher in the areas with high-head dams, and lower downstream of Louisville where older, low-head dams produce higher velocities less conducive to biological activity (Figure V-7).

TABLE V-5

OHIO RIVER SUSPENDED SOLIDS (1968-72)

Location (river miles from mouth)	Winter				Summer			
	No. of samples	15th Percentile	Median	85th Percentile	No. of samples	15th Percentile	Median	85th Percentile
	(mg/l)							
Pittsburgh (981.6)	9	13	18	25	12	4	8	49
Big Sandy (663.8)	9	10	53	71	11	9	32	111
Cane Run (364.4)	12	50	120	170	37	16	27	42
Henderson (177.0)	20	45	165	260	18	18	48	125

Figure V-7 SEASONAL RIVER PROFILES
OHIO RIVER
AMMONIA PLUS ORGANIC NITROGEN



Ammonia, measured separately, shows a different pattern. Ammonia is present in primary sewage treatment discharges, in sewer overflows, and, while it is picked up from fertilizers in runoff, it usually is oxidized to other forms as it travels to rivers and streams. There are peaks in ammonia concentrations near Cincinnati and Louisville throughout the year, probably from municipal and industrial discharges, and increases during high-flow winter months, probably because of sewer overflows (Figure V-8).

The combination of ammonia, organic nitrogen, and nitrate-nitrite data provides interesting indirect evidence of the heightened biological activity that occurs in the Ohio during summer months. The ratios of organic and oxidized forms of nitrogen to the ammonia form are dramatically higher in the summer (Table V-6), indicating that biological activities in the river are converting more ammonia to these other forms of nitrogen in summer than in winter.

Total phosphorus in the Ohio consists primarily (55 to 87 percent) of the insoluble forms (Table V-7). Runoff or scour appears to be responsible for the high concentrations of total phosphorus observed in high-flow winter months (Figure V-9). Median phosphate values at four equidistant stations increased from 0.04-0.17 mg/l in low-flow summer months to 0.08-0.33 mg/l in high-flow winter months.

Dissolved phosphorus, the form most readily used as a nutrient, appears to arise mostly from point sources, because concentrations are generally higher at low flow than at high flow. Dissolved phosphorus accounts for less than half of the total phosphorus, even during the summer.

Salinity, Acidity, and Alkalinity

Acidity. Tributaries to the upper Ohio River, as well as some portions of the Ohio itself, receive large amounts of acidic discharges from active and abandoned mines in Pennsylvania and West Virginia. Many of these tributaries have become so acidic that fish and other aquatic life can no longer survive. The Ohio, however, is large enough to assimilate acid wastes without being significantly affected. The pH levels in the section from Pittsburgh to Steubenville, Ohio, show a slight drop as the river flows downstream, with median pH values dropping from 7.0 at Pittsburgh to 6.5 near Steubenville. Acidic industrial discharges contribute to this pattern. The result is that 11 or 12 stations (depending on season) violate ORSANCO pH standards 15 percent of the time they are sampled.

TABLE V-6

OHIO RIVER NITROGEN CONCENTRATIONS (1968-72)

	Markland Dam		Louisville		Evansville	
	Winter	Summer	Winter	Summer	Winter	Summer
			(median values)			
Concentrations (mg/l as N)						
Ammonia (NH_3)	0.38	0.13	0.36	0.04	0.38	0.03
Organic nitrogen + ammonia (Org N)	2.5	2.0	1.05	0.5	1.0	0.55
Nitrite + Nitrate (NO_2 + NO_3)	1.2	1.9	1.05	1.7	1.05	1.5
Ratios						
$\frac{\text{Org N} + NH_3}{NH_3}$	6.6	15.4	2.9	12.5	2.6	18.3
$\frac{NO_2 + NO_3}{NH_3}$	3.2	14.6	2.9	42.5	2.8	50.0

Figure V-8 SEASONAL RIVER PROFILES

OHIO RIVER

AMMONIA

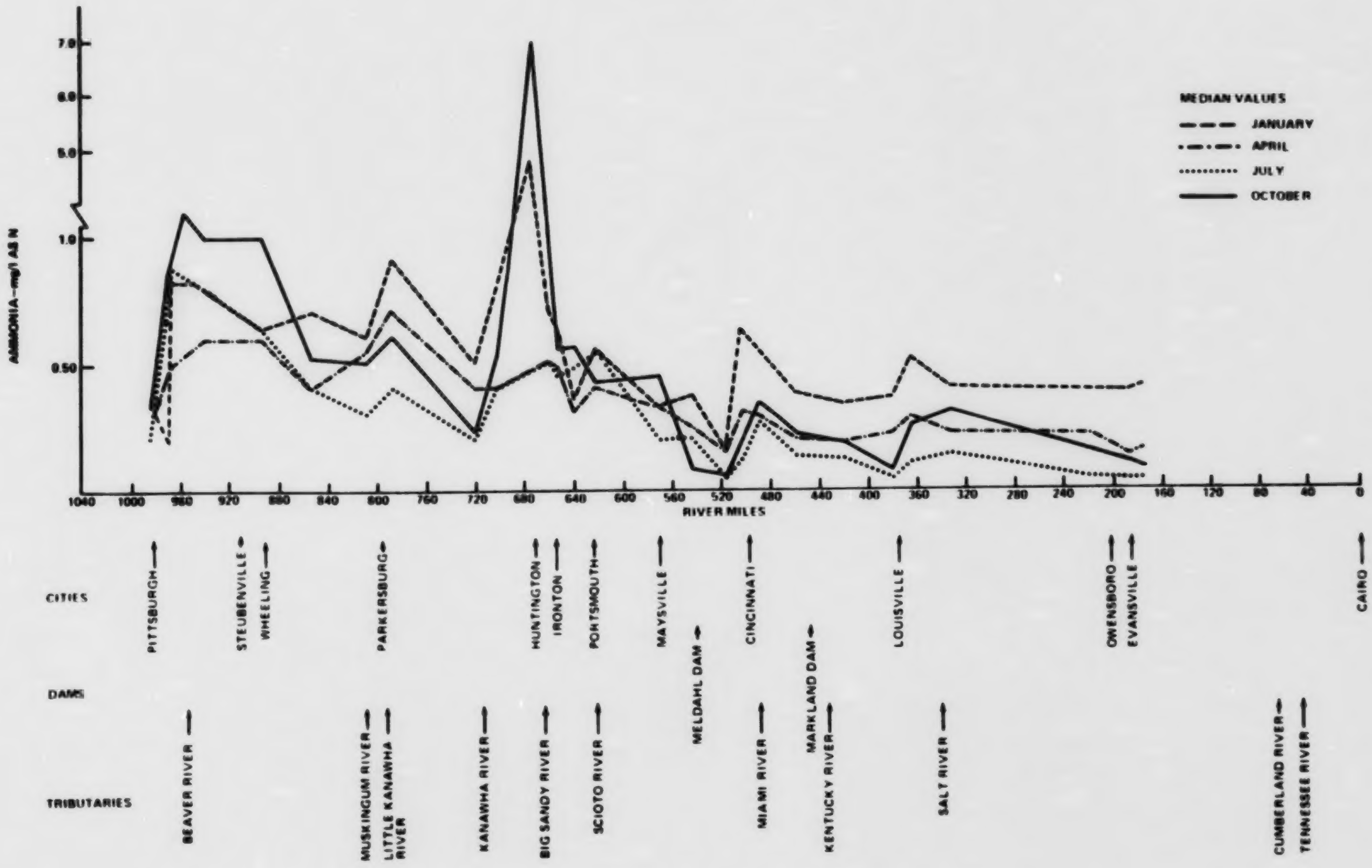


Figure V-9 SEASONAL RIVER PROFILES

OHIO RIVER

TOTAL PHOSPHORUS

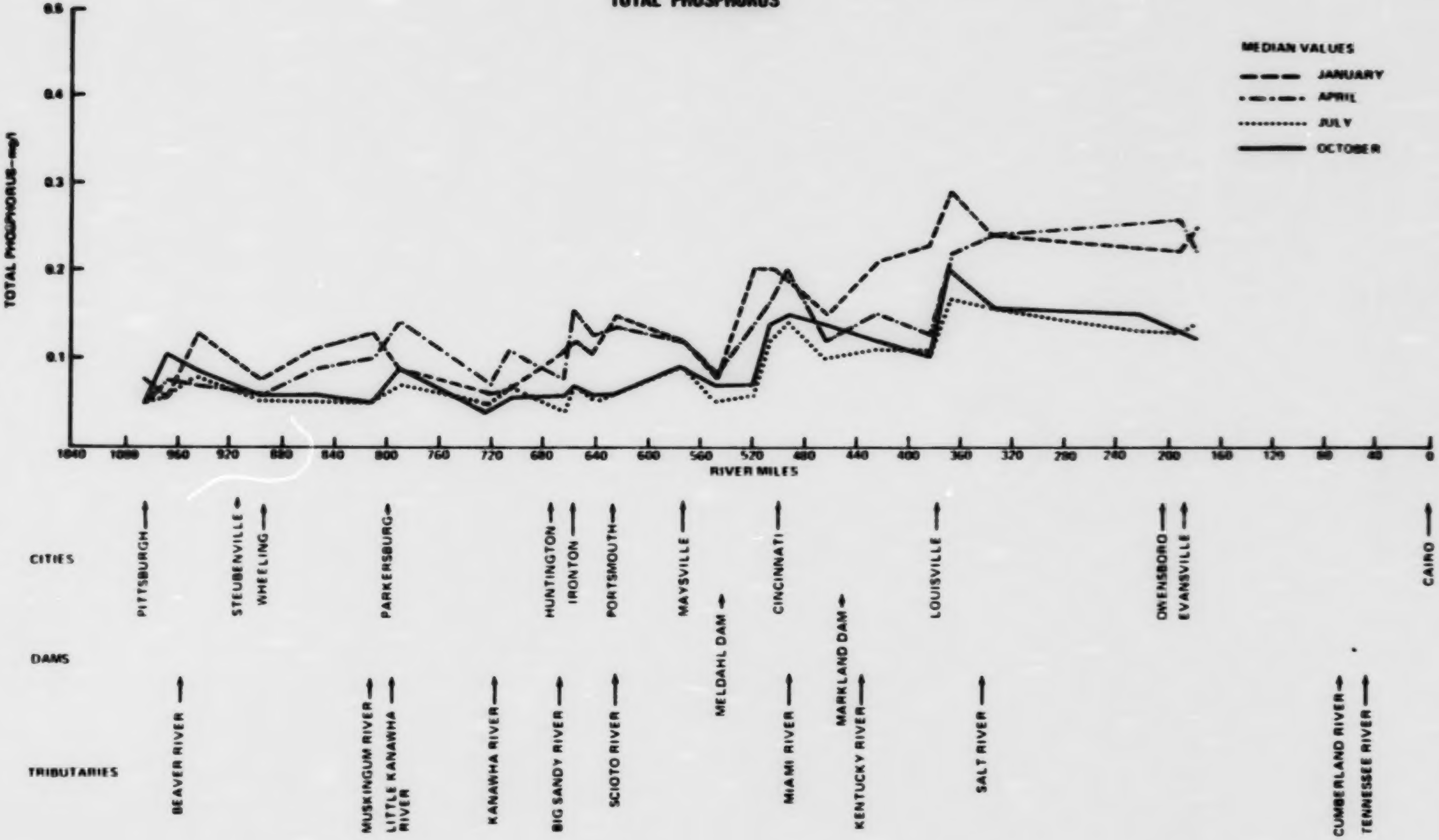


TABLE V-7

OHIO RIVER PHOSPHORUS CONCENTRATIONS (1968-72)

	Markland Dam		Louisville		Evansville	
	Winter	Summer	Winter	Summer	Winter	Summer
			(median values)			
Concentrations (mg/l as P)						
Total phosphorus	0.15	0.14	0.23	0.105	0.22	0.13
Dissolved phosphorus	0.02	0.05	0.036	0.048	0.038	0.059
Percentages						
Dissolved	13	36	16	46	17	45
Insoluble	87	64	84	54	83	55

Downstream from Steubenville, the river recovers to normal pH levels of 7.4-7.5. Table V-8 shows the range of values at four approximately equidistant stations on the Ohio.

The main reason rivers can assimilate acidic wastes, aside from dilution, is that most rivers have a natural alkalinity that acts as a buffering system. In the upper Ohio, acid discharges have consumed so much of this buffering capacity that median alkalinity has been reduced to 10 to 20 mg/l—extremely low compared to most other U.S. rivers (Table V-9). Alkalinity is lowest upstream—near the incoming acidic tributaries and waste discharges—and gradually recovers as naturally alkaline groundwater and tributaries enter the river. Local peaks occur at locations where less acidic tributaries—the Beaver, Muskingum, Miami, Tennessee, and Cumberland Rivers—enter the Ohio. Alkalinity is lower, however, during high-flow quarters, indicating the runoff effect of acid mine drainages, and possibly of the rain itself, which is less alkaline (Figure V-10).

Dissolved Solids. Dissolved solids are generally well below the levels required by local standards (750 mg/l). At four equidistant stations, values of total dissolved solids range from 190-272 mg/l in winter to 240-320 mg/l in summer (Table V-10). The higher levels in summer, when flows are lower, indicate that point sources or relatively constant groundwater inputs are probably responsible. The figures showing conductivity (another measure of dissolved solids) and chlorides (a constituent of dissolved solids) show that peaks occur downstream from the Muskingum River (just above Parkersburg) in all four seasons (Figures V-11 and V-12).

TABLE V-8

OHIO RIVER pH LEVELS (1963-72)

	December-February				June-August			
Location (river miles from mouth)	No. of samples	15th Percentile	Median	85th Percentile	No. of samples	15th Percentile	Median	85th Percentile
				(standard units)				
Sewickley (969.1)	9	6.7	6.8	7.2	10	6.5	6.8	7.0
Big Sandy (663.8)	9	6.2	6.6	6.9	11	6.6	6.8	6.9
Cane Run (364.4)	18	7.0	7.4	7.8	27	6.9	7.4	7.9
Cairo (3.2)	21	7.3	7.5	7.5	11	7.4	7.5	7.6

Figure V-10 PROFILE BY AGGREGATED QUARTERS, 1968-1972

OHIO RIVER

TOTAL ALKALINITY

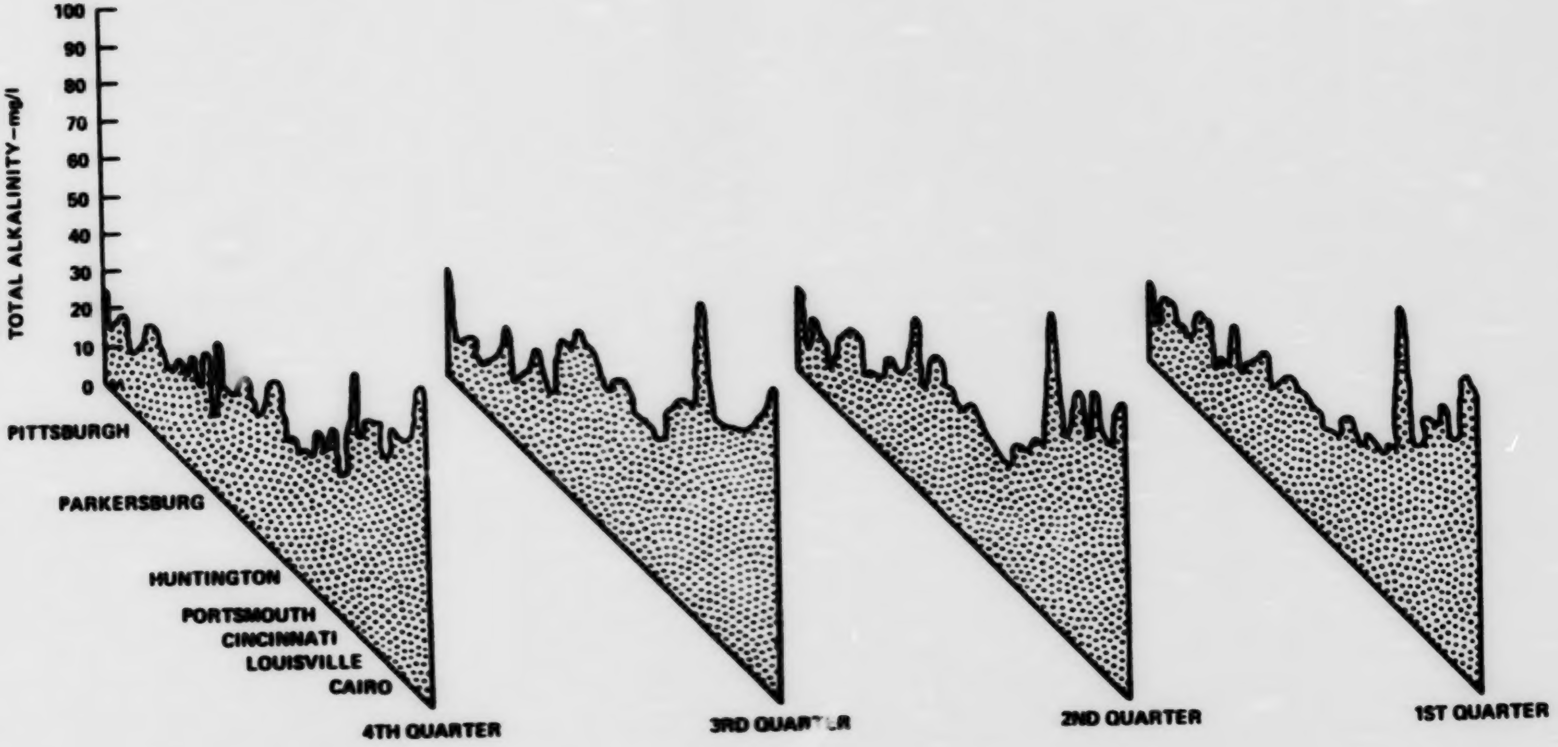


Figure V-11 SEASONAL RIVER PROFILES

OHIO RIVER

CONDUCTIVITY

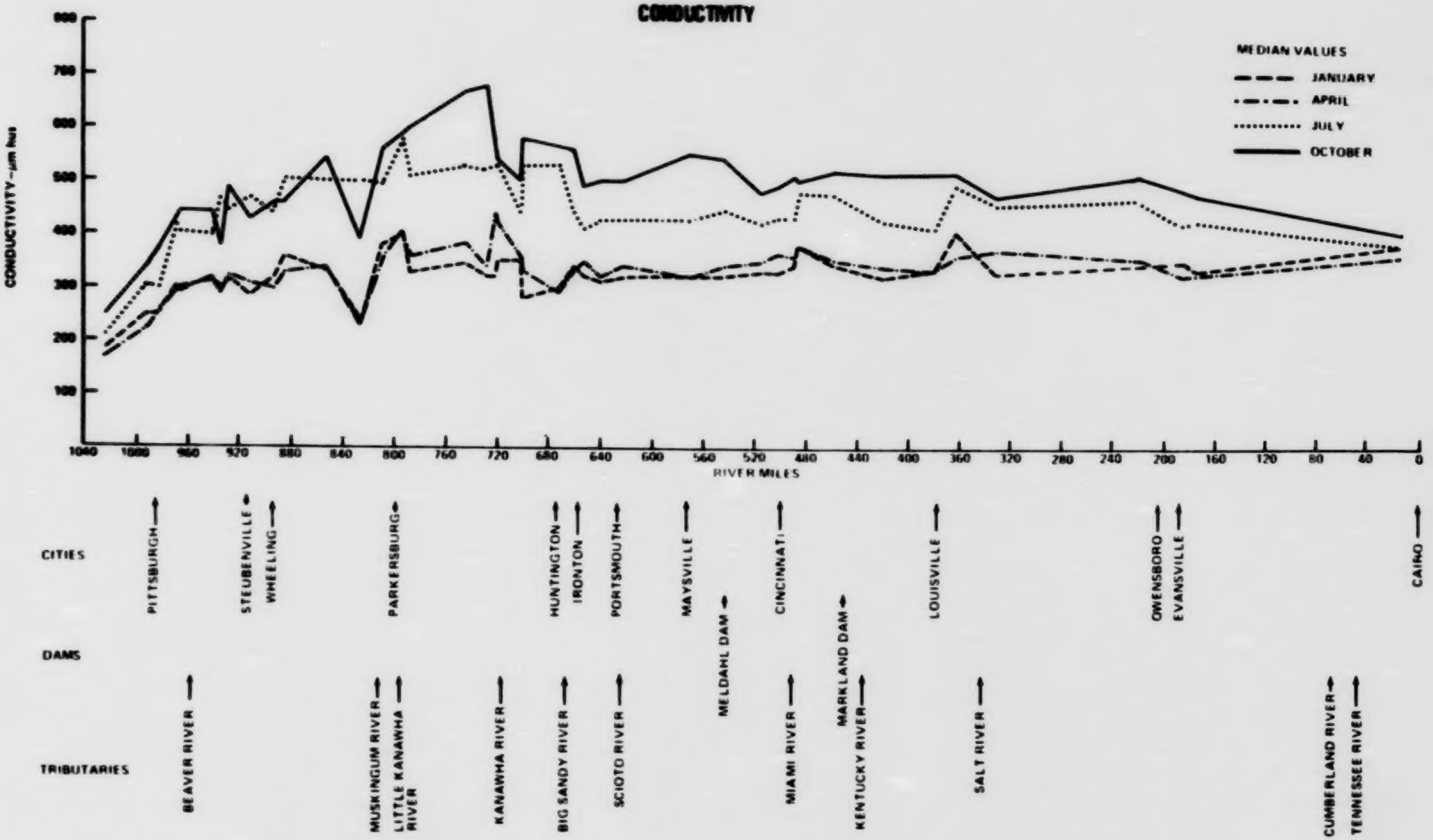


Figure V-12 PROFILE BY AGGREGATED QUARTERS, 1968-1972

OHIO RIVER

CHLORIDES

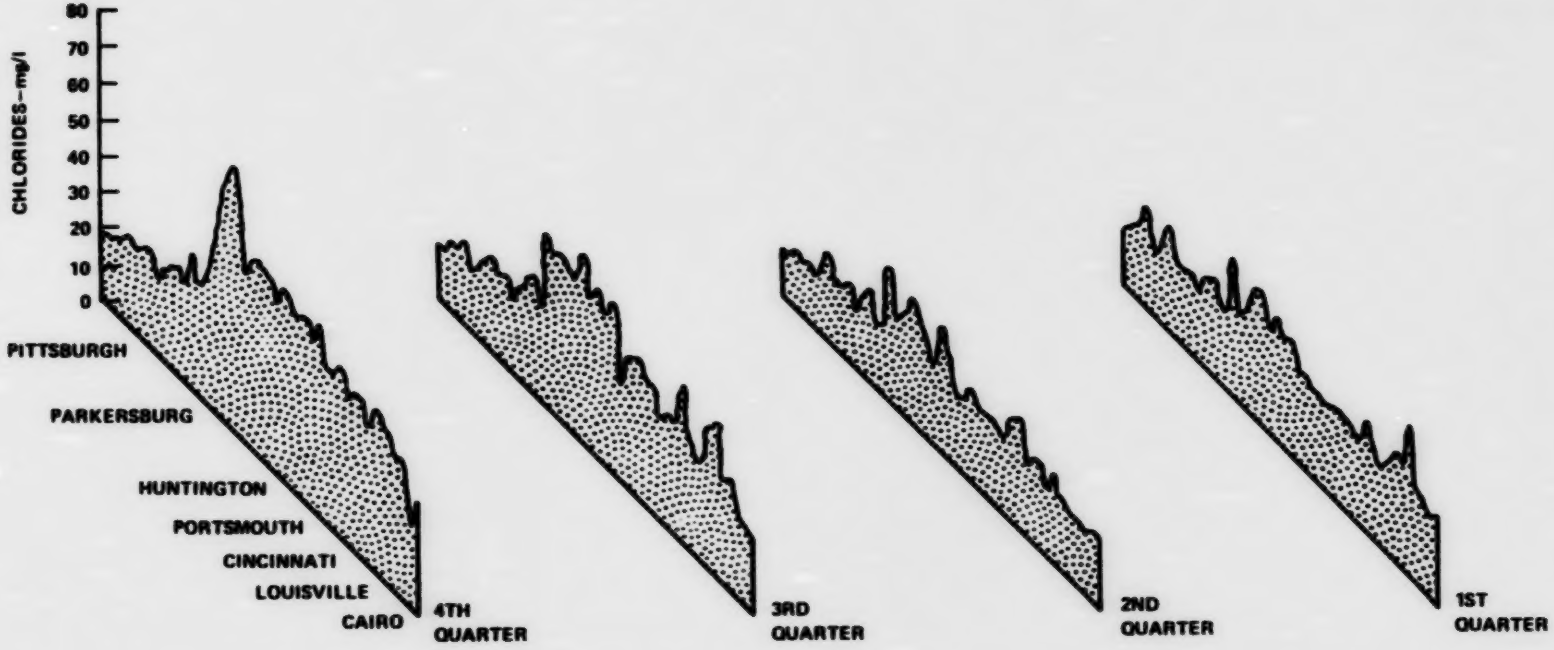


TABLE V-9

OHIO RIVER ALKALINITY (1968-72)

Location (river miles from mouth)	December-February				June-August			
	No. of samples	15th Percentile	Median	85th Percentile	No. of samples	15th Percentile	Median	85th Percentile
		(mg/l)				(mg/l)		
Sewickley (969.1)	8	10	12	13	8	7	11	15
Big Sandy (663.8)	9	25	30	36	11	30	38	50
Cane Run (364.4)	18	47	57	65	47	53	62	84
Cairo (3.2)	21	66	76	91	11	75	93	96

TABLE V-10

OHIO RIVER SALINITY (1968-72)

Location (river miles from mouth)	Conductivity (µmhos)		Dissolved solids (mg/l)		Chlorides (mg/l)	
	Winter	Summer	Winter	Summer	Winter	Summer
			(median values)			
Sewickley (969.1)	302	419	207	265	20	22
Big Sandy (663.8)	340	440	190*	268*	26	28
Cane Run (364.4)	403	490	272	320	30	40
Dam 53 (18.5)	380	406	210	240	24†	21†

*Location at Addison (721.0)
†Location at Cairo (3.2)

Oxygen Depletion

Dissolved oxygen levels are generally well above standards set for the river: in the 1968-72 period only 5 (of 46) stations recorded more than 15 percent of their observations below 4.0 mg/l in any single 3-month season. EPA field studies show that Pittsburgh and Cincinnati municipal discharges cause low dissolved oxygen at times, but the condition is not widespread.

In the winter, oxygen levels are generally above 10 mg/l, except for depressions downstream from Pittsburgh, Wheeling, Huntington, and the Kanawha River. In the other seasons, warming temperatures and lower flows bring generally lower dissolved oxygen throughout the river, with the section below Cincinnati slightly worse than the rest of the river (Figure V-13 and Table V-11).

Seasonal differences tend to disappear when the levels are corrected for the lower solubility of oxygen at higher temperatures. Median oxygen saturation is generally above 75 percent in the upper half of the river all year; below Cincinnati and near Cairo, median saturation declines to as low as 65 percent in the fall (Figure V-14).

No clear trends occurred from 1963-67 to 1968-72 in oxygen levels, except in the section downstream from Pittsburgh. Here oxygen appeared to decline, possibly because of installation of higher-head dams (Figure V-15).

Figure V-13 SEASONAL RIVER PROFILES
OHIO RIVER
DISSOLVED OXYGEN

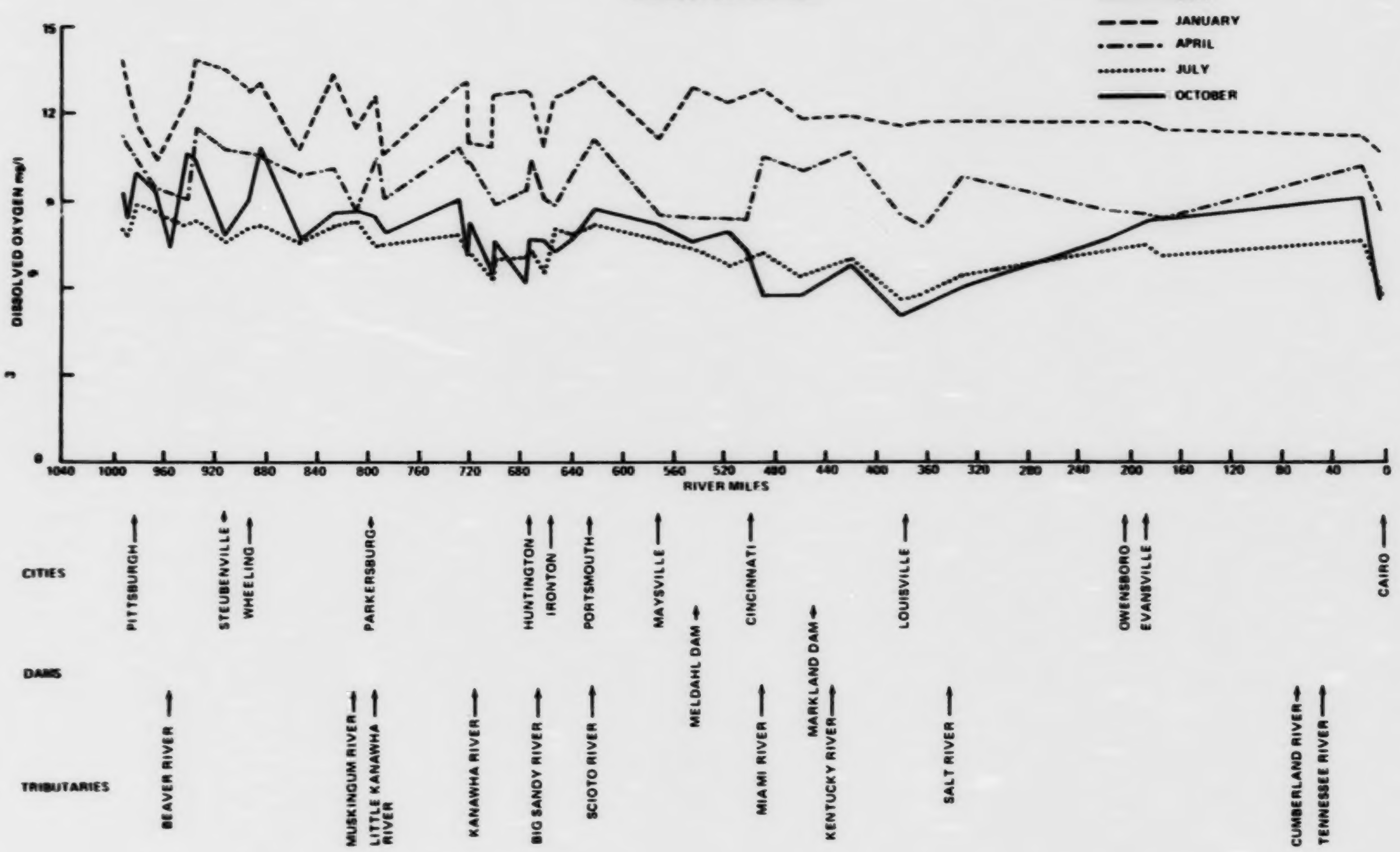


Figure V-14 SEASONAL RIVER PROFILES

OHIO RIVER

DISSOLVED OXYGEN

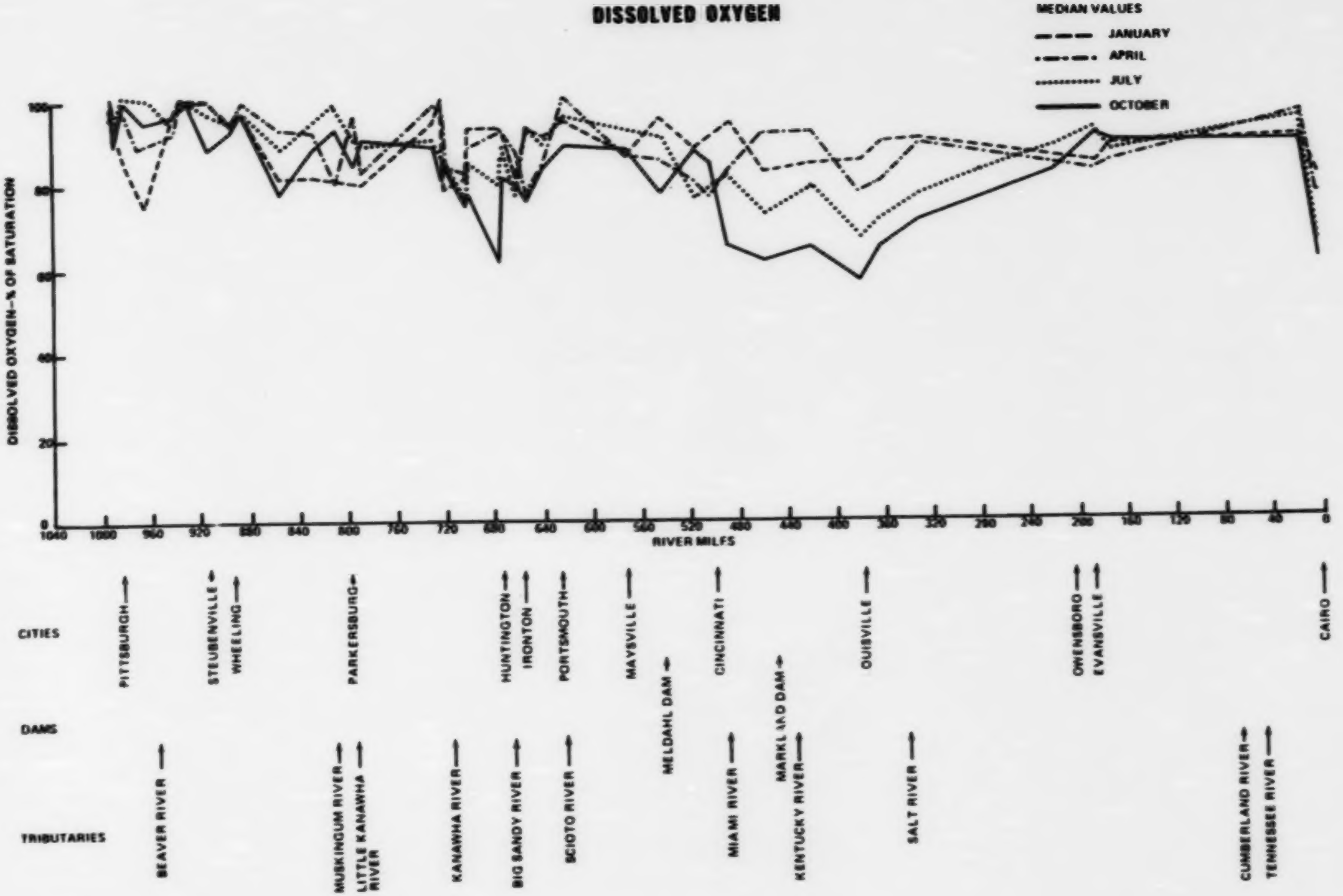


Figure V-15 RIVER PROFILES

OHIO RIVER

DISSOLVED OXYGEN

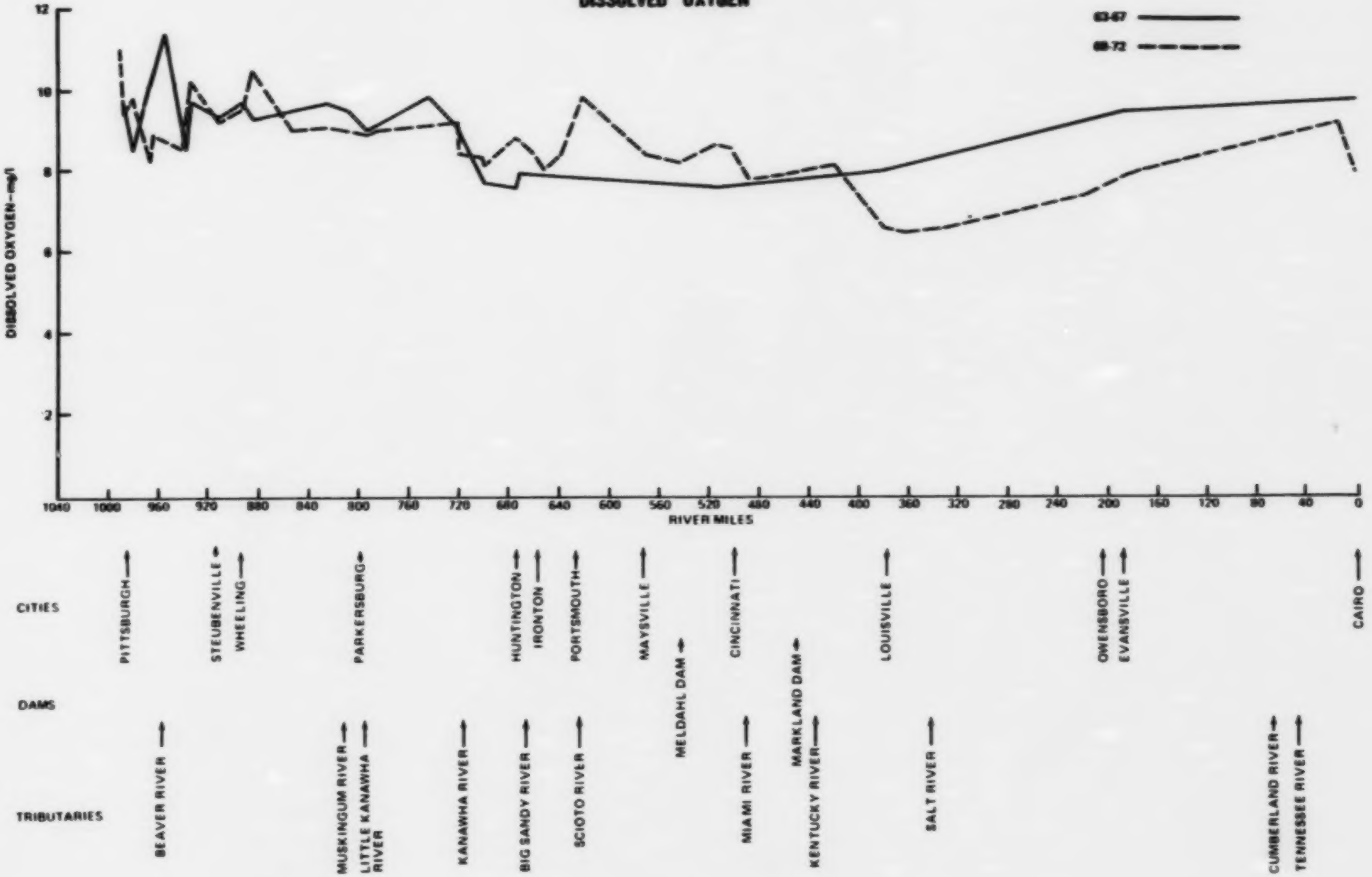


Figure V-16 SEASONAL RIVER PROFILES
OHIO RIVER
BIOCHEMICAL OXYGEN DEMAND

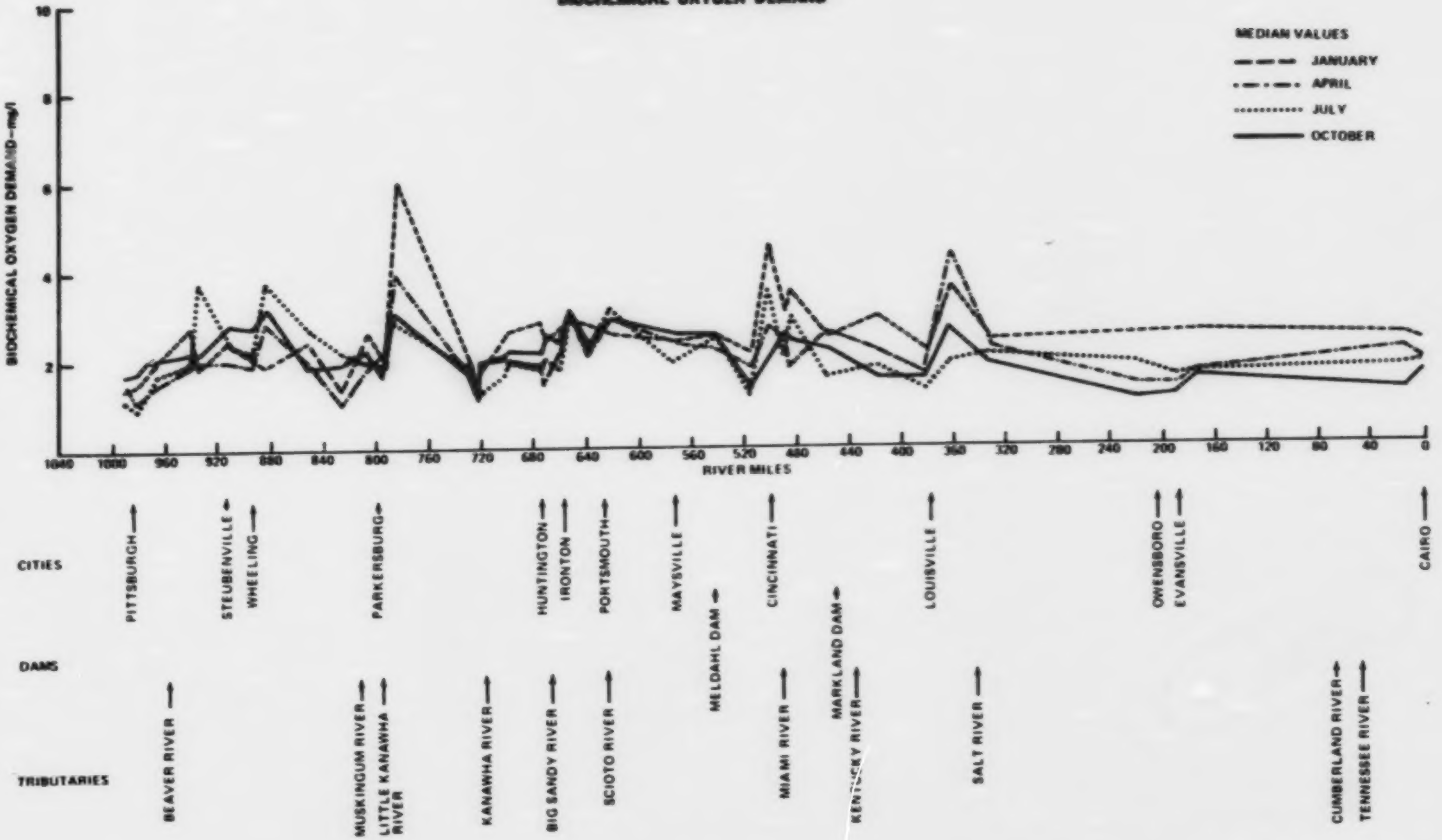


TABLE V-11
OHIO RIVER DISSOLVED OXYGEN (1968-72)

Location (river miles from mouth)	Dissolved oxygen (mg/l) Winter	Dissolved oxygen (mg/l) Summer	Dissolved oxygen (percent saturation) Winter	Dissolved oxygen (percent saturation) Summer
		(median values)		
Pittsburgh (981.6)	11.5	8.2	85.2	104
Big Sandy (663.8)	10.7	6.5	81.7	78.3
Cane Run (364.4)	11.6	5.7	89.8	70.9
Cairo (3.2)	10.5	5.4	80.7	64.1
		(15th percentile values)		
Pittsburgh (981.6)	10.5	7.4	75.4	94.1
Big Sandy (663.8)	9.0	5.6	63.4	66.7
Cane Run (364.4)	10.2	4.4	83.2	53.7
Cairo (3.2)	9.7	4.5	68.3	54.0

Health Hazards and Aesthetic Degradation

Total and fecal coliform levels are particularly high downstream from the Ohio's largest sewage treatment plants in Pittsburgh, Parkersburg, Cincinnati, and Louisville. The standard of 2,400 coliform organisms per 100 ml is being violated at a wide variety of locations on the river in both winter and summer. On the other hand, special local studies show improvements in the past 5 years near several cities. The average location on the Ohio registers coliform counts higher than 88,000 per 100 ml in 15 percent of winter observations; the summer value is 238,000 (Table V-12). Coliforms are one of four pollutants that violate standards at the average station on the Ohio; the others are phosphorus, iron, and manganese (Table V-13).

TABLE V-12
OHIO RIVER COLIFORM COUNTS (1968-72)

Location (river miles from mouth)	Total coliforms (no./100 ml) Winter	Total coliforms (no./100 ml) Summer	Fecal coliforms (no./100 ml) Winter	Fecal coliforms (no./100 ml) Summer
Pittsburgh (981.6)	3,200	8,900	490	370
Big Sandy (663.8)	3,800	14,000	400	590
Cane Run (364.4)	100,000	650,000	6,200	47,000
Dam 53 (18.5)	1,300	1,000	400	400
		(85th percentile values)		
Pittsburgh (981.6)	22,000	42,000	1,200	1,000
Big Sandy (663.8)	14,000	37,000	1,800	1,200
Cane Run (364.4)	350,000	3,900,000	40,000	240,000
Dam 53 (18.5)	1,800	1,500	420	500
(Mean of 37-39 stations)	(88,000)	(238,000)	(3,000)	(18,000)

TABLE V-13

OHIO RIVER: COMPARISON WITH STANDARDS (1968-72)

	85th Percentile concentrations		Criteria or Standard* (mg/l unless shown)	Mean station exceeds standard†
	Winter	Summer		
Dissolved iron	2.74	0.84	0.30 (NTAC)	Yes
Dissolved manganese	0.50	0.39	0.05 (NTAC)	Yes
Nitrate plus nitrite (as N)	1.35	1.72	10 (PHS)	No
Total phosphorus	0.29	0.15	0.10 (EPA)	Yes
Alkalinity	28.8‡	33.5‡	20‡ (NTAC)	No
pH (standard units)	6.7‡-7.3	6.8‡-7.4	6.5‡ -8.5 (ORSANCO)	No
Chlorides	34	43	250 (PHS)	No
Dissolved solids	214	264	750 (ORSANCO)	No
Dissolved oxygen	9.7‡	5.9‡	4‡ (ORSANCO)	No
Total coliforms (no./100 ml)	87,700	238,000	2400 (ORSANCO)	Yes

*ORSANCO specifies numerical standards for four pollutants; other criteria are developed by the National Technical Advisory Committee (NTAC), EPA, or the Public Health Service (PHS) for national consideration, but not necessarily for every stream and river.

†Standards exceeded in 15 percent or more of 1968-72 samples.

‡15th Percentile concentrations; standard stated as a minimum level, not as a maximum.

VI. TENNESSEE RIVER

Water in the Tennessee River is of good quality except for undesirable levels of bacteria below the urban areas (Chattanooga and Knoxville, Tenn., and Decatur and Florence, Ala). Dissolved oxygen levels are very high throughout the river except below Knoxville and Watts Bar Lock and Dam. Eutrophication is not a problem in the Tennessee River. Nitrogen and phosphorus levels are typically low but nitrate levels may be increasing.

The key pollutants highlight conditions in the Tennessee:

- *Harmful Substances.* Fish containing mercury have been found in the North Fork Holston River, Pickwick Landing Reservoir, and Kentucky Reservoir. Releases from known major sources of mercury have been reduced to acceptable levels, and a sampling program of bottom sediments and fish flesh is continuing. Heavy metals are within permissible ranges, with levels reduced in the current 5-year period.

- *Physical Modification.* The general physical quality of the Tennessee River is good. Discharge from the lower levels of a storage reservoir during the summer months can cause significant temperature changes in the downstream river reach. In the Tennessee Valley, however, this has affected only the Clinch River below Norris Dam.

- *Eutrophication Potential.* Nitrogen and phosphorus levels are low in the main stem reservoirs; nitrate levels appear to be increasing. Aquatic weed growth has been heavy in Pickwick and Guntersville reservoirs, but aquatic growths are not a problem in the other reservoirs.

- *Salinity, Acidity, and Alkalinity.* The Tennessee is good for fresh waters in terms of the broad chemical indicators of acidity and salinity.

- *Oxygen Depletion.* Throughout the river, dissolved oxygen levels are more than sufficient to support aquatic life; the only detectable problems are below Knoxville and the water released from Watts Bar Lock and Dam.

- *Health Hazards and Aesthetic Degradation.* The bacteriological criteria for recreation are met along the Tennessee River, except for below Chattanooga and Knoxville municipal waste treatment discharges. Criteria are also violated below Florence and Decatur, Ala., because of municipal discharges and small amounts of runoff.

GENERAL PHYSICAL DESCRIPTION

The Tennessee River drains 41,000 square miles from parts of seven States having a 1965 basin population of 3.2 million people (Figure VI-1). Of the four major SMSA's in the basin, three are located on the main stem of the Tennessee, representing a 1970 population of 933,000. Of these, the two largest areas—Chattanooga and Knoxville, Tenn.—depend on the Tennessee River as a source of drinking water.

The main stem of the Tennessee starts 655 miles above the Ohio River where the Holston and French Broad Rivers join. The river contains nine dams and reservoirs operated by the Tennessee Valley Authority (TVA) for flood control, navigation, and power production. Together they provide 12.4 million acre-feet of storage. All of the dams have navigation locks and range in height from 50 to 100 feet (Table VI-1).

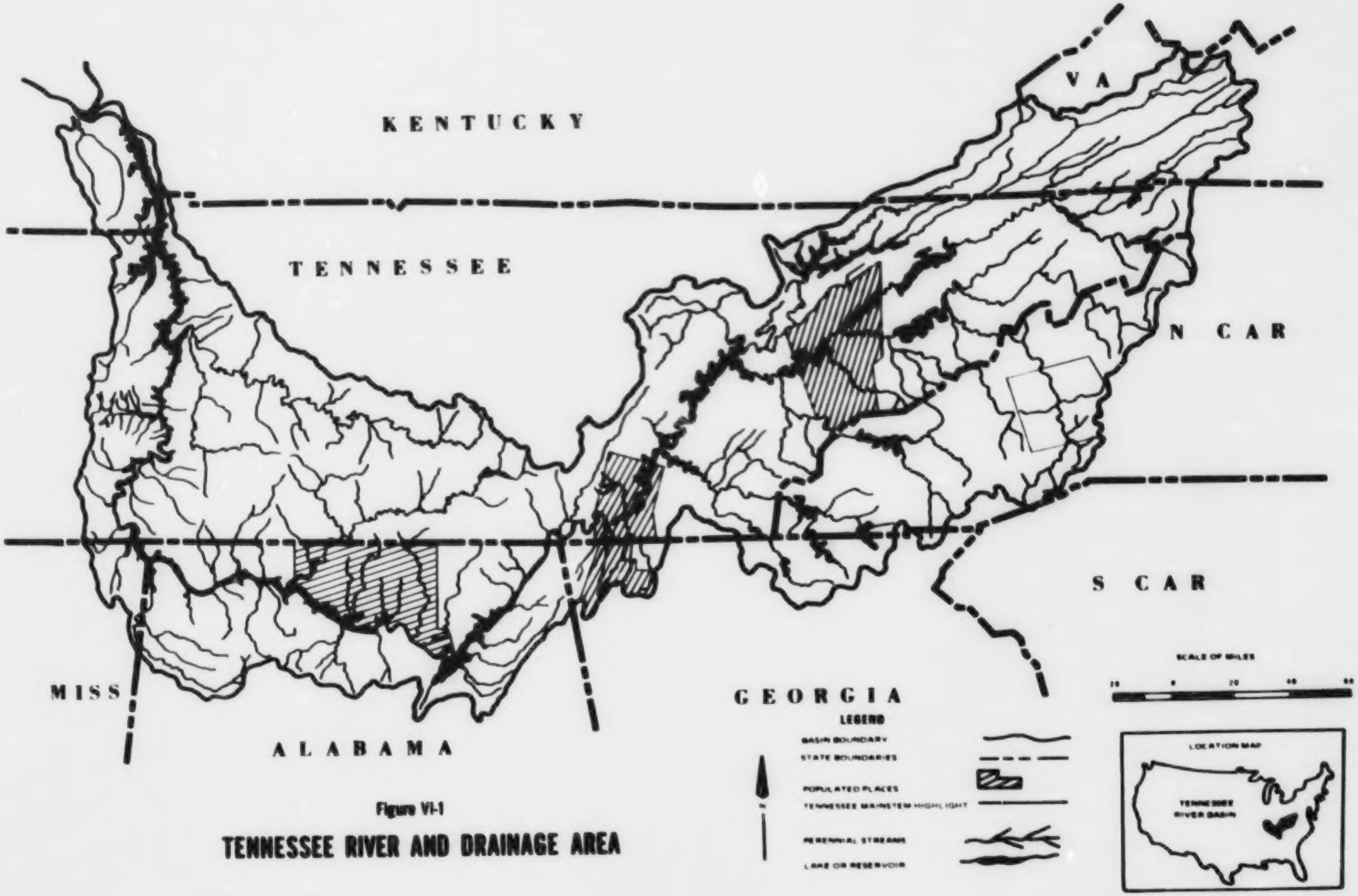

KENTUCKY
VA
TENNESSEE
N CAR
S CAR
MISS
ALABAMA
GEORGIA
SCALE OF MILES
10
0
20
40
60
LEGEND
BASIN BOUNDARY
STATE BOUNDARIES
POPULATED PLACES
TENNESSEE MAINSTEM HIGHLIGHT
PERENNIAL STREAMS
LAKE OR RESERVOIR
N
LOCATION MAP
TENNESSEE RIVER BASIN

Figure VI-1

TENNESSEE RIVER AND DRAINAGE AREA

Storage reservoirs located on the tributaries to the Tennessee River are designed to store water during periods of peak flow and release it during periods of low flow. The reservoirs are drawn down during late summer, fall, and early winter, and then allowed to slowly absorb peak spring flows until they reach normal full pool levels in early summer. The water levels in the main stem reservoirs fluctuate less than the levels in the tributary reservoirs because navigable depths must be maintained at all times. Tributary reservoirs, typically much deeper than main stem reservoirs, exhibit strong thermal stratification during warm summer months, as well as density flow effects. Main stem reservoirs show these effects to a much lesser degree because they are relatively shallower and pass a larger volume of water. Main stem reservoirs are less subject to density flow effects and are better characterized by the "plug flow" phenomenon.

An average of 52 inches a year of precipitation occurs in the basin, nearly all in the form of rain. More than half of the yearly rainfall occurs from November to mid-April; the driest months are September and October. The runoff volume in an average year is equivalent to 22 inches of rainfall over the entire basin. Flows in the main stem from rainfall are modified by reservoir storage and releases (Figure VI-2).

The nine reservoirs, with their 625,000 acres of water surface and 11,000 miles of shoreline, are used extensively for water-based recreation and fishing. In 1970, over 47 million visitors used the reservoirs and adjacent areas for swimming, water skiing, boating, fishing, canoeing, picnicking, and other leisure activities.

TABLE VI-1

TENNESSEE RIVER: MAIN STEM DAMS AND RESERVOIRS*

Dam (river miles from mouth)	Approximate depth at dam (feet)	Gross volume (millions of acre-feet)
Kentucky (22.4)	85	6.0
Pickwick (206.7)	90	1.1
Wilson (259.5)	100	0.65
Wheeler (274.9)	65	1.2
Guntersville (349.0)	60	1.0
Nickajack (424.7)	50	0.25
Chickamauga (471.0)	75	0.70
Watts Bar (529.9)	70	1.1
Fort Loudoun (602.3)	90	0.39
Total		12.39

*Source: Tennessee Valley Authority

POLLUTION PROBLEMS AND SOURCES

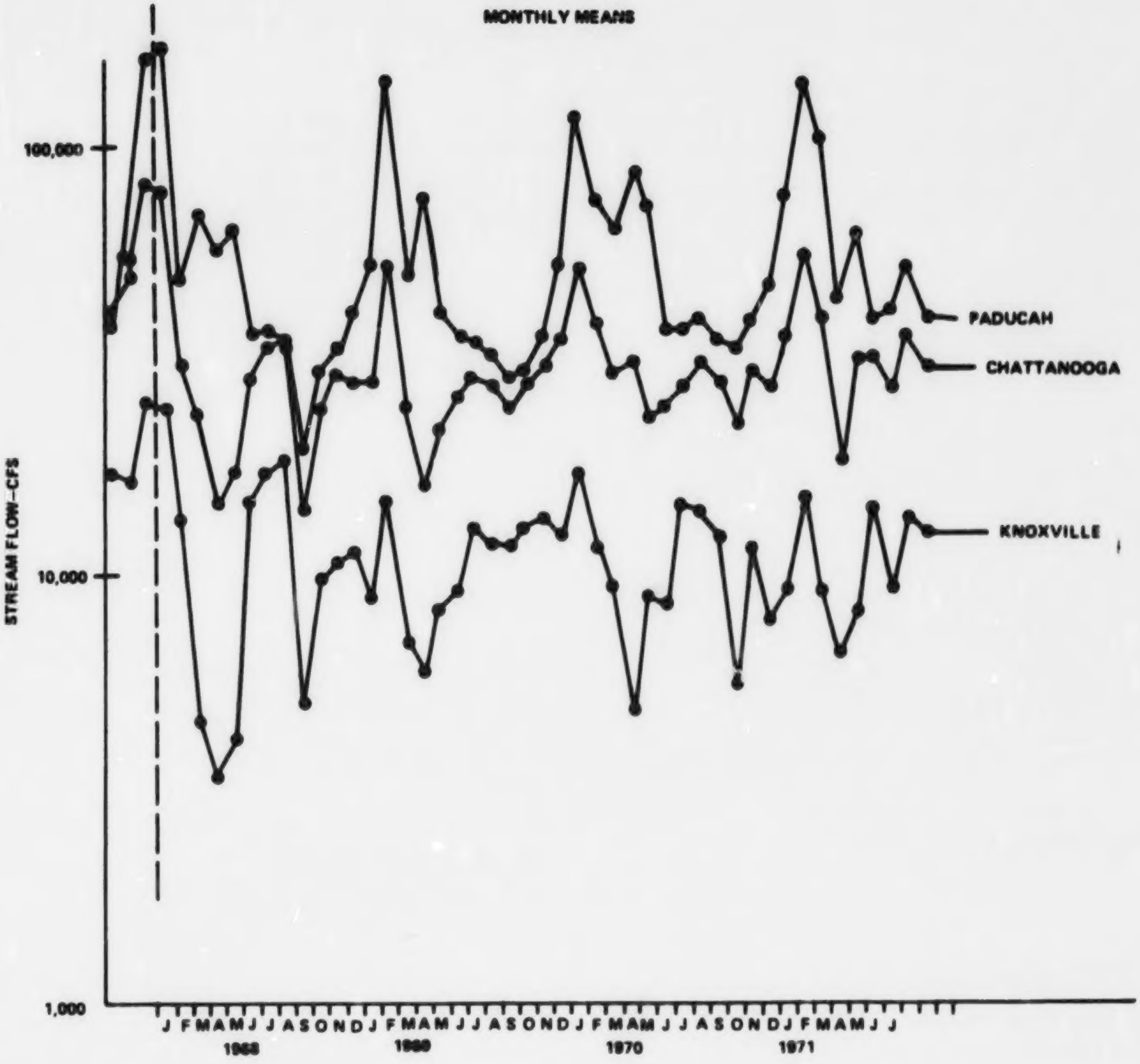
Wastes from the three largest urban areas along the main stem of the Tennessee River affect water quality in parts of the reservoirs. Bacteriological effects threaten waters designated for recreation use because of combined storm and sanitary sewers in Chattanooga and Knoxville, and because of sewer infiltration problems and runoff from Huntsville, Ala. About 68 percent of the organic loadings of the Chattanooga waste treatment facility arise from industries; the figure for the Knoxville facility is 80 percent.

Mining activity is extensive throughout the tributary basins: phosphate is extracted in the Duck and Elk basins; mica, feldspar, and clay are mined in the French Broad basin; marble is quarried near Knoxville; copper is mined in the Hiwassee basin; and coal is mined in the Clinch, Emory, and Sequatchie basins, and along the Tennessee River main stem in northern Alabama. Mining in the tributary areas can impair water quality by siltation and acid drainage.

Figure VI-2 TIME TRENDS AT RIVER MILEPOINTS

TENNESSEE RIVER

STREAM FLOW



Reservoirs and dams produce both beneficial and deleterious effects. They produce hydroelectric power, smooth out variations in streamflow, settle out suspended silt, and allow bacteria from sewage sources to die off. On the other hand, water in the lower depths of reservoirs can become low in, or devoid of, dissolved oxygen. This problem is more serious in deep water storage reservoirs, such as those found on the tributaries to the Tennessee main stem. Dissolved oxygen levels on the main stem reservoirs are generally quite good. However, discharges from the lower reaches of the reservoir during the summer months sometime violate DO criteria for aquatic life. This condition has occurred most frequently at Watts Bar Lock and Dam. TVA is investigating various means of attaining and maintaining acceptable levels of DO in releases from such structures.

DATA AND METHOD

Most of the data in STORET for the Tennessee River was collected by TVA. Its general policy has been to focus sampling on one reservoir each year. For example, Fort Loudoun, the furthest upstream reservoir of the nine-reservoir chain, was sampled in 1971. This reservoir is fed at the upstream end by the Holston and French Broad Rivers (Figure VI-3). Knoxville, a city of one half million population stretching along the reservoir (RM 637 to RM 652), has sewer outfalls and diffusion pipes at two locations (RM 646.2 and RM 640). The Little River (RM 610 to RM 625) is followed by 25 miles of embayments and the 95-foot Fort Loudoun Dam (RM 602.3). Samples were taken at nine stations at monthly intervals in 1971. Temperature and dissolved oxygen were measured at 10-foot depths. Nutrients, coliforms, and metals were measured 1 foot below the surface and at one or two deeper points depending on reservoir depth.

WATER QUALITY CONDITIONS

Harmful Substances

Excessive levels of mercury have been found in fish in three areas: the North Fork of the Holston River and the Pickwick Landing and Kentucky Reservoirs, both on the Tennessee main stem. Releases from known sources of mercury have been reduced to acceptable levels, and monitoring is continuing to determine reductions in concentrations in bottom sediments and in the flesh of fish taken from the waters.

The soils in the Tennessee basin are rich in iron, and high levels in the water are associated more with surface runoff than waste discharges. Iron, although not toxic, can interfere with some aquatic activity and drinking water supplies. Total iron concentrations doubled from 1960-68 to 1969-72 in Nickajack, Pickwick, and Kentucky Reservoirs, and showed slight improvements in Guntersville and Wheeler. Dissolved iron concentrations, however, changed little, and values for all reservoirs are 100 ug/l or below, well below the permissible standard for drinking water. Local and temporary exceptions to this level do occur, however, apparently caused by industrial waste discharges. One example occurred on Aug. 23, 1971 in the Fort Loudoun reservoir (Figure VI-4).

Lead concentrations are negligible, with all reservoirs showing values around 10 ug/l. Four EPA stations in the Tennessee River recorded concentrations for heavy metals and radioactivity from 1962 through 1969. High concentrations of heavy metals were recorded more frequently in 1964-66 than 1962-63. Data collected after 1966 generally decreased from these values; however, there are not enough data to place a high confidence in this conclusion. Finally, more high values were reported in the upstream reach than downstream. Several violations of public water supply criteria for arsenic and cadmium occurred in 1965 and 1966. Gross alpha and beta radioactive levels are well below water supply criteria in all waters of the main stem.

Physical Modification

The Tennessee main stem is dominated by nine dams and reservoirs. The storage reservoirs on the tributaries are typically much deeper than main stem reservoirs and exhibit both strong thermal stratification during warm summer

Figure VI-3

FORT LOUDOUN RESERVOIR, TENNESSEE RIVER

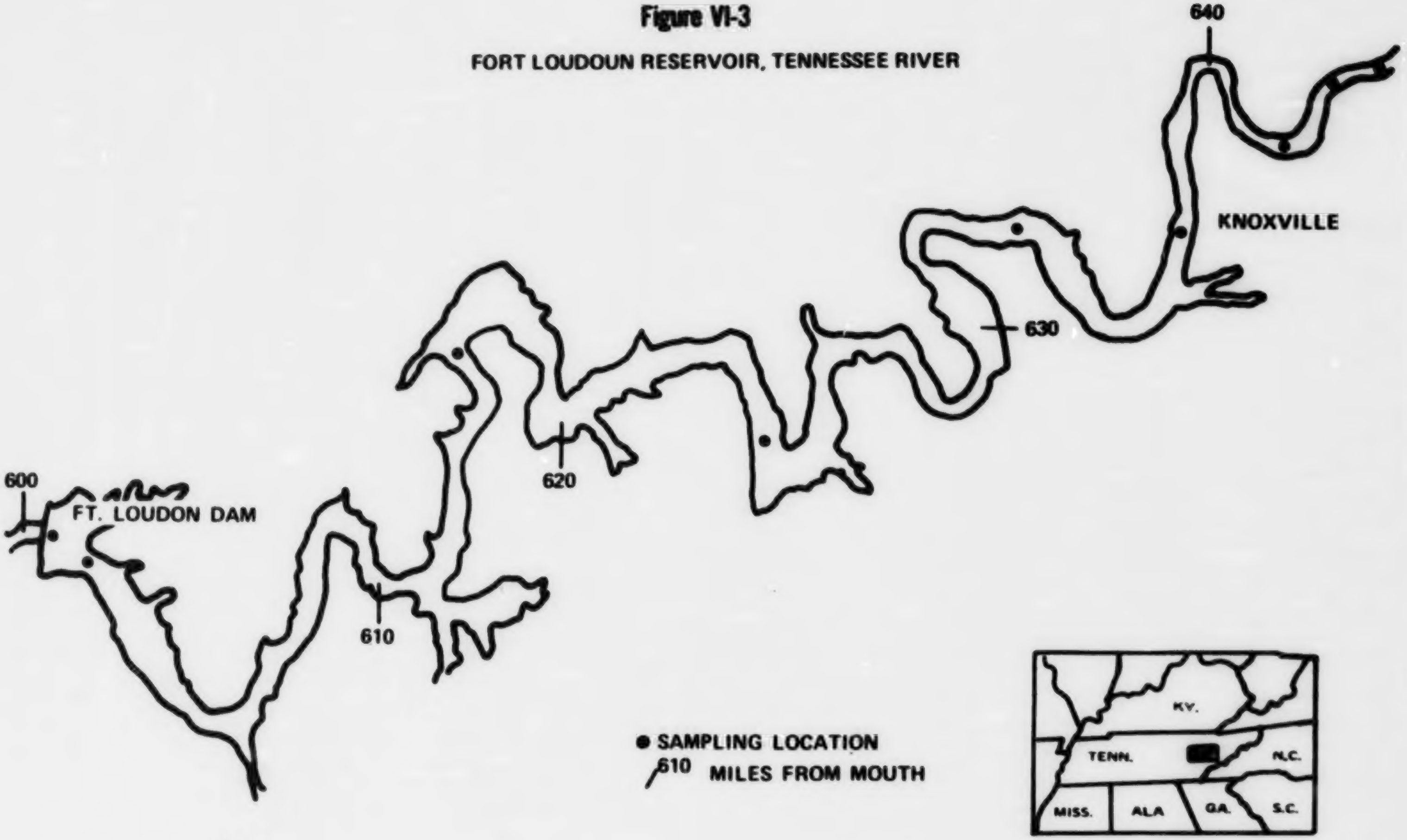

640
KNOXVILLE
630
620
610
600
FT. LOUDON DAM
● SAMPLING LOCATION
610 MILES FROM MOUTH
KY.
TENN.
N.C.
MISS.
ALA
GA.
S.C.

Figure VI-4 **DEPTH ANALYSIS**

TENNESSEE RIVER

IRON

TOTAL IRON–μg/l

FT. LOUDOUN–JULY DATA

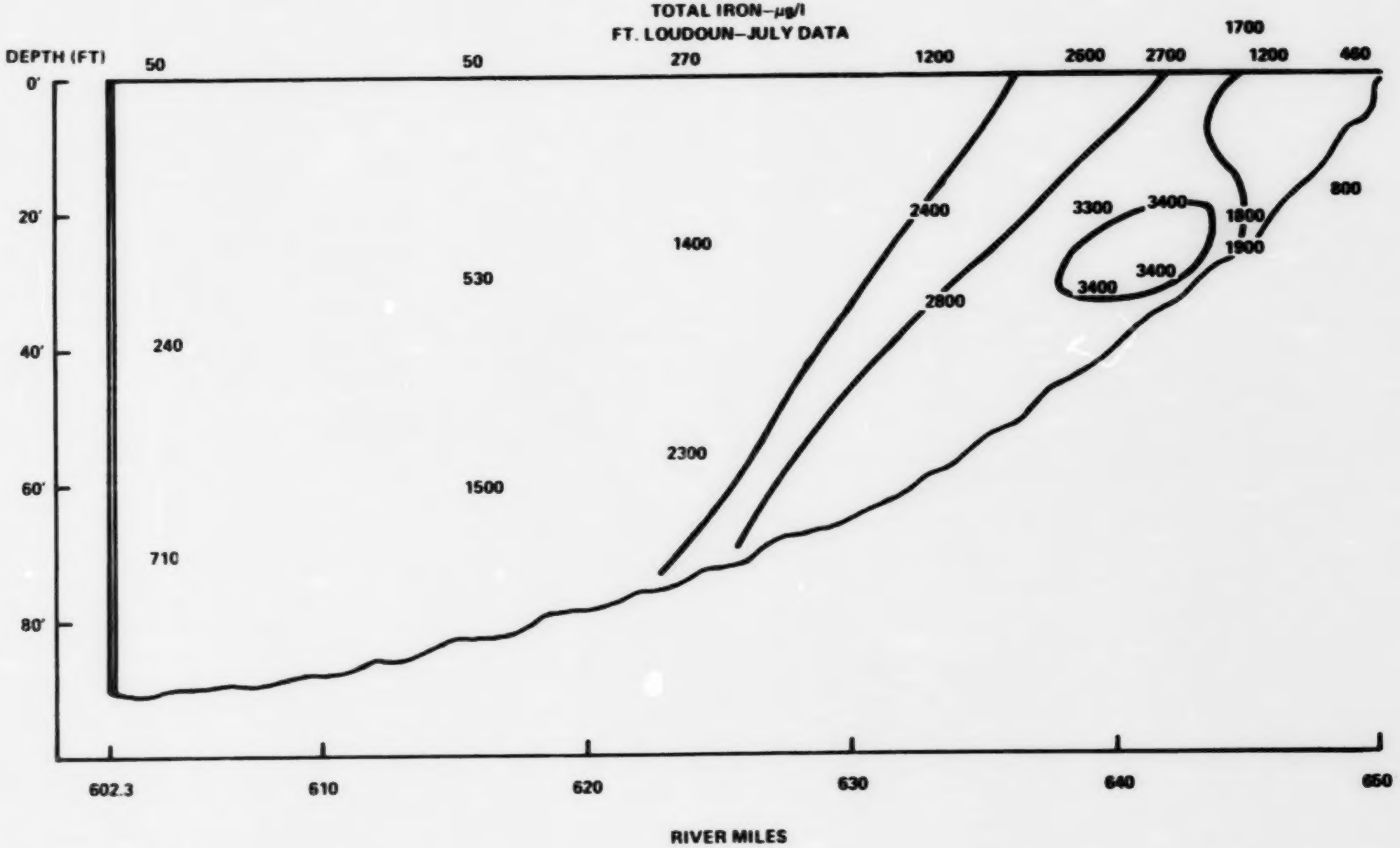
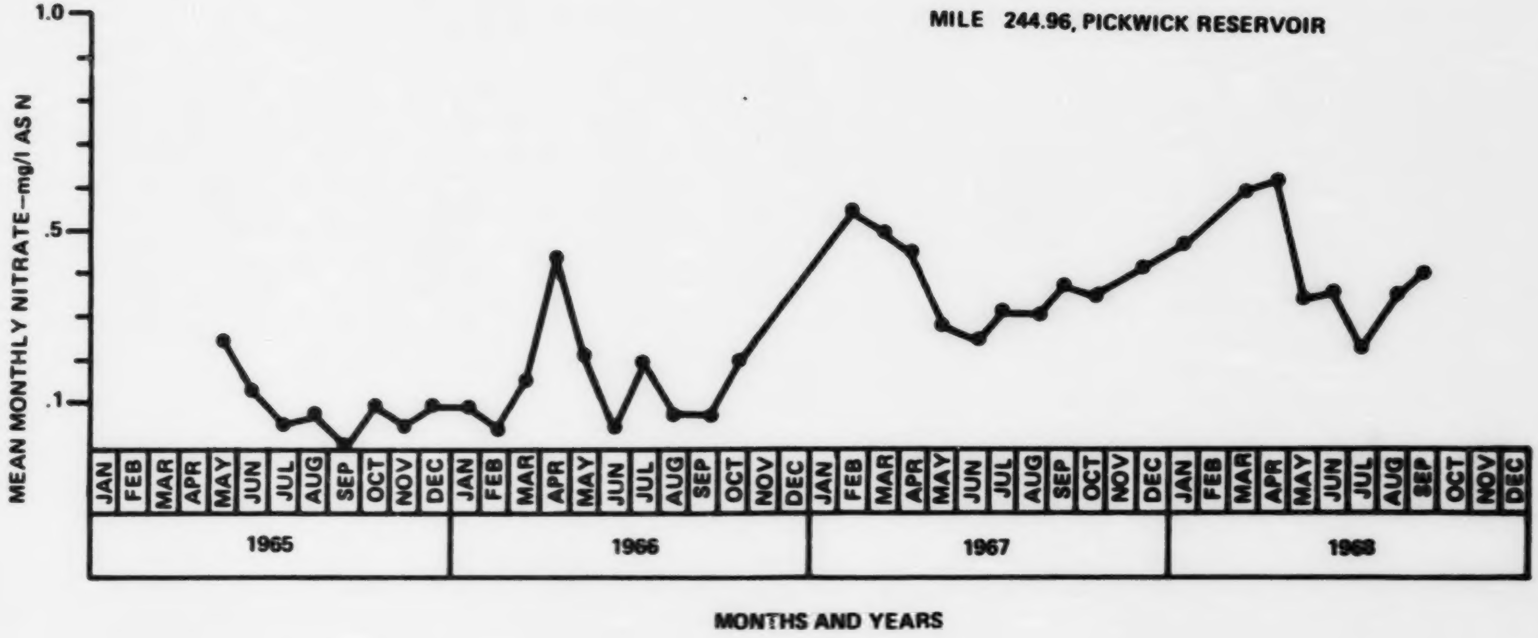


Figure VI-5 TIME TREND AT RIVER MILEPOINT

TENNESSEE RIVER

NITRATES



months and density flow effects. Main stem reservoirs show these effects to a lesser degree because they are relatively shallower and pass a larger volume of water. Reservoirs used for power generation discharge density layers and waters with low dissolved oxygen levels through the penstocks.

Eutrophication Potential

A change in laboratory techniques for nitrates in January 1967 makes trend analyses hazardous. However, the generally increasing values of the data allow at least a suspicion that levels in the whole reservoir chain are increasing (Table VI-2). In addition, a study of Fort Loudoun and Pickwick reservoirs revealed that maximum concentrations of nitrates occur primarily during periods of high flow (Figure VI-5). Because so little is known of the effects of agricultural and urban runoff on the ecology of the Valley, it is difficult to assign total responsibility to these sources, but they are certainly large contributory factors. Total phosphates and soluble orthophosphates show slight increases in some reservoirs. Organic nitrogen increased from 0.16 to 0.27 mg/l in Guntersville and Wheeler; concurrently, ammonia for these same reservoirs increased from 0.01 to 0.06 mg/l. Although changes in laboratory techniques may be partially responsible for these increases, none of these values are high; taken together, however, they may be indicative of a continuing increase of organic matter in these reservoirs. In Fort Loudoun, Pickwick, and Kentucky, the organic nitrogen level decreased; ammonia decreased in Fort Loudoun, but remained the same in Pickwick and Kentucky (Table VI-3).

Nitrogen and phosphorus concentrations in the reservoirs are not limiting aquatic growth. The seasonal uptake of nutrients shows increasing levels of biological activity, and while the aging of a water body is a natural and inevitable eutrophication process, the nutrients from agricultural runoff and industrial and municipal discharges may be accelerating the natural eutrophication process in the Tennessee Valley.

TABLE VI-2

TENNESSEE RIVER NITRATE LEVELS

Reservoir (river miles from mouth)	1962	1963	1964	1965	1966	1967*	1968	1969	1970	1971	1972	1973
						(annual average, mg/l)						
Fort Loudoun (531 to 573)	0.06	0.04							0.45			
Guntersville (350)			0.06	0.02								
Wheeler (277 to 284)				0.02	0.08			0.36	0.31	0.43	0.41	0.53
Wilson (263 to 265)						0.28	0.34					
Pickwick (208 to 258)				0.08	0.15	0.34	.038					
Kentucky (23 to 102)					0.11	0.25	0.30	0.33			0.46	

*Laboratory analysis method for nitrates changed in January 1967.

Salinity, Acidity, and Alkalinity

Water quality along the main stem is good, with pH generally between 7.5 and 8.5. Chlorides range from 10 to 20 mg/l, with improvements occurring in Fort Loudoun, Nickajack, Wheeler, and Pickwick Reservoirs; there are no changes in Guntersville and Kentucky Reservoirs. Alkalinity levels range generally from 40 to 60 mg/l.

TABLE VI-3

TENNESSEE RESERVOIRS: NUTRIENT LEVELS

Reservoir	Organic nitrogen		Ammonia		Total phosphate (PO_4)		Soluble phosphate (PO_4)	
	1960-68	1969-72	1960-68	1969-72	1960-68	1969-72	1960-68	1969-72
	(medians, mg/l)							
Fort Loudoun	0.39	0.30	0.15	0.06	0.15	0.24	0.06	0.10
Watts Bar	0.12		0.01	0.01	0.14	0.15		
Chickamauga								
Nickajack		0.06		0.07				0.08
Guntersville	0.17	0.27	0.01	0.05	0.12	0.13	0.05	0.05
Wheeler	0.15	0.27	0.01	0.07	0.15	0.15	0.08	.10
Wilson	0.38		0.08		0.14		0.08	
Pickwick	0.32	0.19	0.08	0.08	0.22	0.22	0.15	
Kentucky	0.39	0.21	0.04	0.04	0.29	0.33	0.14	0.17

Oxygen Depletion

Dissolved oxygen medians generally show slight improvements or no change and are well above the criteria for aquatic life, according to the TVA 1973 report, "Water Quality in the Tennessee Valley"; exceptions occur 9 miles downstream of Knoxville and below Watts Bar Lock and Dam. The dissolved oxygen median in Kentucky Reservoir does not indicate that conditions have gotten worse in this reservoir, but reflects the warmer months during which 1969-1972 surveys were conducted (Table VI-4).

Dissolved oxygen in lower levels of reservoirs can be lower in the summer months, as is true in Fort Loudoun (Table VI-5). Dissolved oxygen values in the tailraces of Watts Bar and Pickwick Dams are representative of waters in the lower levels of the reservoir. (Figure VI-6). Readings for Watts Bar tailrace are 3 mg/l in the summer months. Even in the deepest regions of reservoirs on the main stem Tennessee, dissolved oxygen is never fully depleted.

TABLE VI-4

TENNESSEE RESERVOIRS: DO, BOD_5 AND COD

Reservoir	Dissolved oxygen		BOD_5		COD	
	1960-68	1969-72	1960-68	1969-72	1960-68	1969-72
	(medians - mg/l)					
Fort Loudoun	6.3	7.2	2.1	1.4	12	8
Watts Bar	7.8	7.2	1.2	1.3		
Chicamauga	8.2	8.3	1.5			
Nickajack	7.8	8.2	1.4	1.0		6
Guntersville	8.2	8.1	1.4	1.6		6
Wheeler	8.1	8.7	1.7	1.2		6
Wilson	8.3	8.3	2.1			
Pickwick	7.9	8.5	1.8	1.7	14	6
Kentucky	8.2	7.1	1.7	1.5	14	6

Figure VI-6 **TIME TRENDS AT RIVER MILEPOINTS**

TENNESSEE RIVER

DISSOLVED OXYGEN

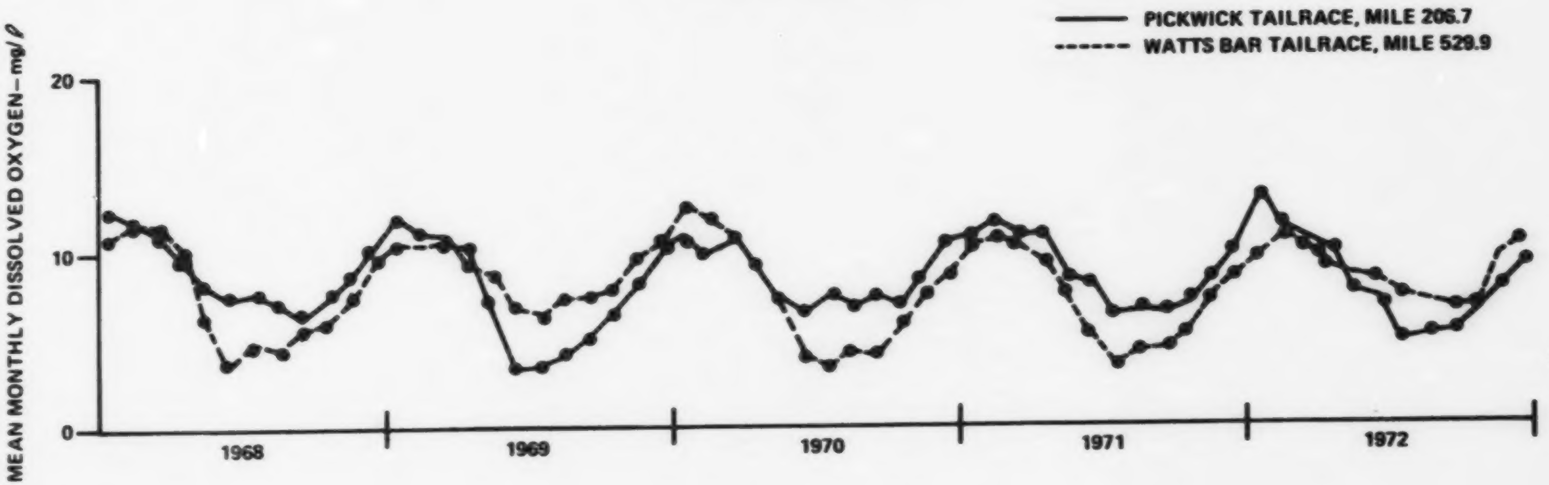


TABLE VI-5

FORT LOUDOUN RESERVOIR: DISSOLVED OXYGEN LEVELS (1971)

Month	Upper reservoir		Lower reservoir	
	0 to 15 feet	Greater than 15 feet	0 to 15 feet	Greater than 15 feet
	(dissolved oxygen in mg/l)			
January	11.0	11.0	10.6	10.6
February	11.9	11.9	11.6	11.6
March	9.7	9.7	9.7	9.8
April	9.7	9.5	10.8	9.0
May	7.8	7.8	9.3	7.1
June	8.2	8.1	8.5	7.4
July	6.7	6.6	6.3	3.9
August	4.7	4.7	5.1	3.8
September	5.5	5.5	6.3	5.2
October	5.7	5.5	5.0	4.6
November	7.0	6.9	6.6	6.4
December	10.4	10.2	9.8	9.9

BOD_5 medians show little change in the different reservoirs, with perhaps slight improvements in some areas. Values are generally low—usually 1 to 2 mg/l—with noticeable seasonal changes in Fort Loudoun Reservoir (Table VI-5). COD medians show low levels, with improvements in the three reservoirs with data for the two time periods.

Health Hazards and Aesthetic Degradation

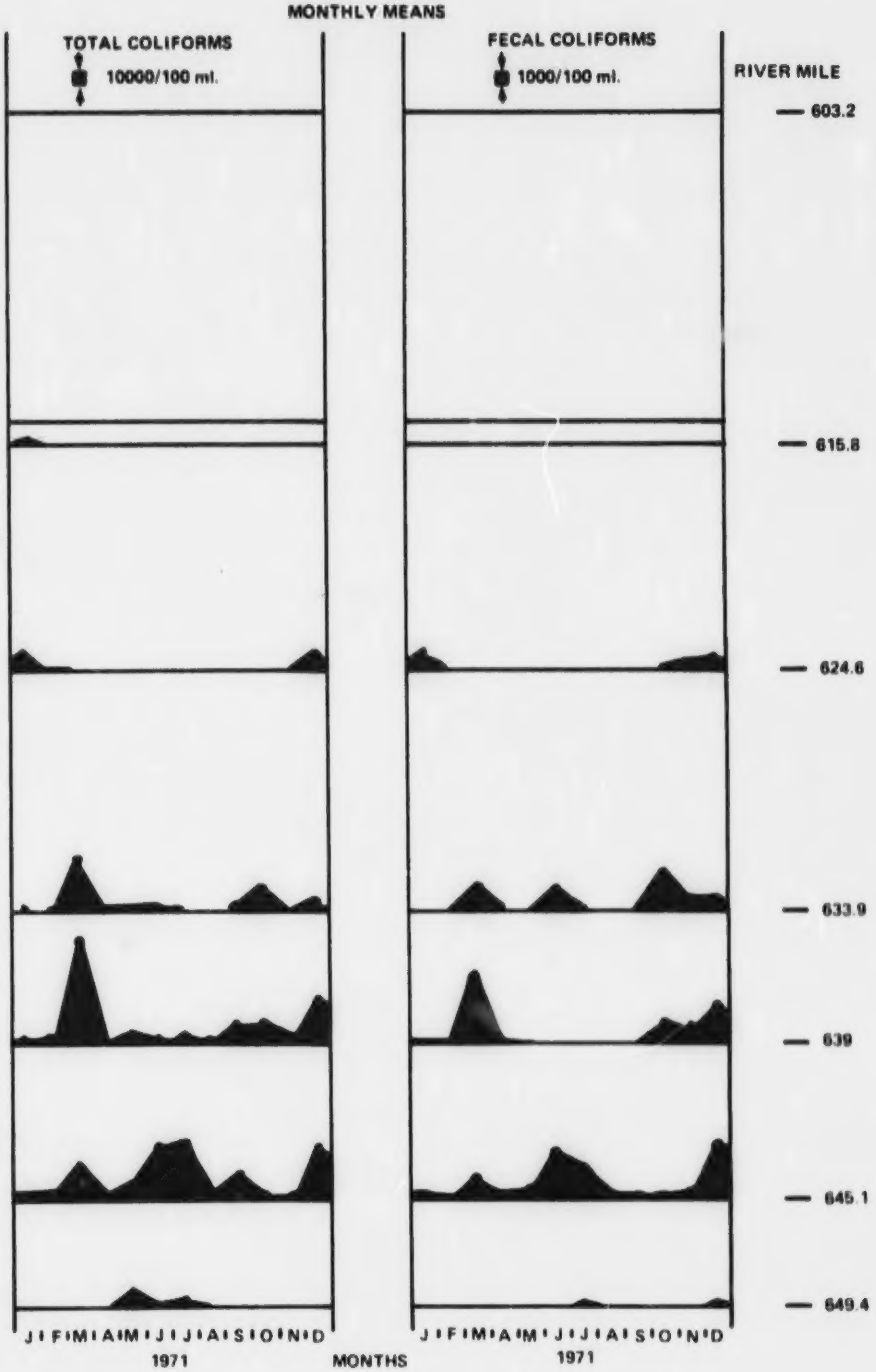
Fecal and total coliform counts are very low throughout the river because of dilution and die-off near large population centers where municipal sewage, runoff, and combined sewer discharges are great, counts are higher. Swimming areas in the reservoirs are generally located away from municipal sewage outlets—that is, where the bacteriological quality is generally quite good. However, below major cities, the coliform levels frequently violate water quality criteria for water-contact recreation. In the past, Chattanooga sewage discharges rendered water unsuitable for 35 miles; recent improved waste treatment at Chattanooga has made water suitable for all uses except along the immediate waterfront of the city and in the area just downstream from the waste treatment plant. The Decatur, Ala., and Florence-Sheffield, Ala., population centers pollute their downstream reach for about 5 miles.

Coliform organisms are quite high for 15 miles in the reservoir downstream of Knoxville (Figure VI-7). In a number of months, the permissible criteria set for public water supplies (10,000 coliforms/100 ml and 2,000 fecal coliforms/100 ml) are greatly exceeded. The criterion for contact recreation is even more stringent, making the water hazardous for this use even more frequently. In a study of the Fort Loudoun reservoir, the coliform data showed no consistent gradient with depth; however, at some locations, there is a slight lateral gradient, indicating a greater population on one side of the reservoir than the other. On the whole, however, the coliform population is probably subject to the vagaries of dispersion, flow, and different growing conditions at different periods of the year. High values for total and fecal coliforms were recorded on one bank of the reservoir at RM 645.1 on June 6, 1971. Total coliforms numbered 122,000/100 ml, and fecal numbered 8,400/100 ml. Low values were recorded at the farthest downstream reach of the reservoir, RM 602.3, as would be expected. The median value at this location was 40/100 ml for total coliforms and 10/100 ml for fecal.

Figure VI-7 TIME TRENDS AT RIVER MILEPOINTS

TENNESSEE RIVER

COLIFORMS



VII. DETROIT AREA

The focal point for water quality in southeastern Michigan is the Detroit area and the many waste dischargers along the lower two-thirds of the 30-mile-long Detroit River. Water quality measurements such as suspended solids, phenols, pH (acid), chlorides, ammonia, cyanides, and iron have improved noticeably over the past 10 years. Phosphorus loadings to Lake Erie were reduced significantly in 1971-73 over the preceeding 10 years. Measurements such as nitrates, dissolved oxygen and coliforms, which tend to be associated with municipal discharges, have changed little, with some worsening. Tributaries in the area generally show improved conditions, the most notable being the Clinton and Rouge Rivers. Three tributaries—Belle, Pine, and Black Rivers—show good quality, with the Raisin River having mixed conditions.

The key pollutant measurements highlight the changing conditions in the Detroit area:

- *Harmful Substances.* Cyanides are present in the Detroit River and two tributaries—the Rouge and Raisin Rivers; in the Detroit River, however, cyanides are lower than they were 5 years ago. Iron levels also show improvement.
- *Physical Modification.* The general physical quality of the Detroit River is good. Temperatures are naturally cool but do show a 1 to 4°C increase along the shore of the lower river, reflecting localized effects of heat discharges. Suspended solids in the river were markedly lower in the past 5 years. Temperatures in tributaries are typical of smaller rivers, showing no unusual conditions.
- *Eutrophication Potential.* Ammonia levels in the Detroit River decreased over the past 10 years, while nitrates showed a worsening trend. Phosphorus levels near the river shore showed point source effects with overall loadings to Lake Erie decreasing two-thirds in the past two years as a result of reduced municipal and industrial discharges. Because of its short length and high flow rates, the Detroit River itself is not subject to eutrophy. However, the river discharges nutrients to Lake Erie where the potential for eutrophication is much higher. Conditions at the mouths of the tributaries, particularly the Clinton River, improved.
- *Salinity, Acidity, and Alkalinity.* Water quality for these pollutants is generally good and improving, despite large acid and chloride discharges. Chloride levels are significantly higher in the lower Detroit River below industrial discharges than upstream, but have improved markedly in the past 5 years. Acid discharges impact the middle segment of the river along the shore, causing a localized depression in pH; conditions improved slightly over the past 10 years.
- *Oxygen Depletion.* Dissolved oxygen levels are generally quite satisfactory along the Detroit River, with a gradual decline along the shore near the mouth where the water becomes shallower and velocities decrease. There is a slight indication of a worsening condition, but the data are limited. Low dissolved oxygen is a noticeable problem at the mouths of the Rouge, Raisin, and Clinton Rivers, but has improved over the past 10 years.
- *Health Hazards and Aesthetic Degradation.* Total coliforms in the lower Detroit River and some tributaries remained generally unchanged to higher over the past 10 years. Median total coliform densities from 5,000 to 10,000 counts per 100 ml are not uncommon. The median level during July-September 1968-72 was above 50,000 in the lower 15 miles of the Detroit River. Areas downstream from combined sewer overflows had high counts along the shore, and in the center of the river further downstream after mixing. Data indicate the continued problem of combined sewer overflows, primarily during rainy periods, with coliforms being high enough to threaten water contact recreation activities. Phenol discharges to the Detroit River are measurable along the shore, but median levels downstream from waste discharges are half those of 5 years ago.

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GENERAL PHYSICAL DESCRIPTION

The southeastern Michigan drainage area consists of seven tributary rivers that drain into the St. Clair River, Lake St. Clair, Detroit River, and Lake Erie (Figure VII-1). Within the 6,000-square-mile drainage area, there are three SMSA's–Detroit, Ann Arbor, and Monroe (part of the Toledo-Monroe Area)–with a 1970 population of almost 4.6 million.

The Detroit and St. Clair Rivers (forming the International Boundary) are the connecting waters between Lakes Huron and Erie. Their annual average flow is 170,000 to 180,000 cfs; monthly extremes are relatively low compared to smaller rivers, ranging from 99,000 to 242,000 cfs. High flows occur in July-August and low flows in February (Figure VII-2). The seven tributaries have annual average flows between 111 and 720 cfs and drainage areas ranging from 434 to 1,034 square miles.

POLLUTION PROBLEMS AND SOURCES

Principal waste sources (transportation, steel, and chemical industries, plus municipal discharges) are concentrated along the lower 20 miles of the Detroit River; combined sewer overflows predominate in the upper 10 miles. While recent trends are markedly improved, in 1962-64 these sources contributed large quantities of pollutants, including 3.3 million pounds per day of chlorides, 1.5 million pounds of suspended solids, and 0.7 million pounds of BOD_5 (Table VII-1). Smaller concentrations of industrial and municipal discharges are spread throughout the seven smaller drainage areas. The 1972 EPA Priority Basin Plan for the drainage area identified 16 principal municipal and 34 principal industrial dischargers (Table VII-2).

DATA AND METHOD

Routine monitoring data (1963-72) were collected at the mouths of each tributary and at selected cross sections of the Detroit and St. Clair Rivers. The International Boundary divides both rivers down the middle; only sampling stations located in U.S. waters (Michigan) were used.

The tributaries were sampled once or twice a month throughout the year, while the two large rivers were sampled generally from April through November when ice conditions are not present (Table VII-3).

Because the Detroit and St. Clair Rivers are short, narrow, and deep for the amount of flow, they have average velocities as high as 5 miles per hour. This condition provides good vertical mixing but little horizontal mixing. Consequently, wastes discharged from the shore tend to stay close to the shoreline as they move downstream. Due to these mixing patterns, river sampling at selected mile points consists of a number of locations at each cross section. Studies have shown that vertical mixing makes depth sampling unnecessary. River profiles of the Detroit River were prepared to show water quality levels along the shore, in the middle of the river, and in some cases the entire cross section. Data were also analyzed for each 3-month interval (quarter) to determine any seasonal changes.

The discussion of water quality generally excludes the St. Clair River and emphasizes the Detroit River and seven tributaries. Water entering the Detroit River is essentially the same quality as that leaving Lake Huron and passing through the St. Clair River (Table VII-4).

WATER QUALITY CONDITIONS

Harmful Substances

Data for 1966-72 show the presence of cyanide in the lower Detroit River and at the mouths of the Rouge and Raisin Rivers. The highest levels of cyanide are found in the lower Detroit River (RM 8.7). Median concentrations are 0.01-0.02 mg/l, but maximum levels reach 0.10 to 0.15 mg/l. There has been no significant improvement in median values over the 7 years, although the extreme values have improved. The tributaries have essentially no cyanide in the current 5 years, an improvement over 2 years earlier (Table VII-5).

Figure VII-1 AREA MAP

DETROIT AREA

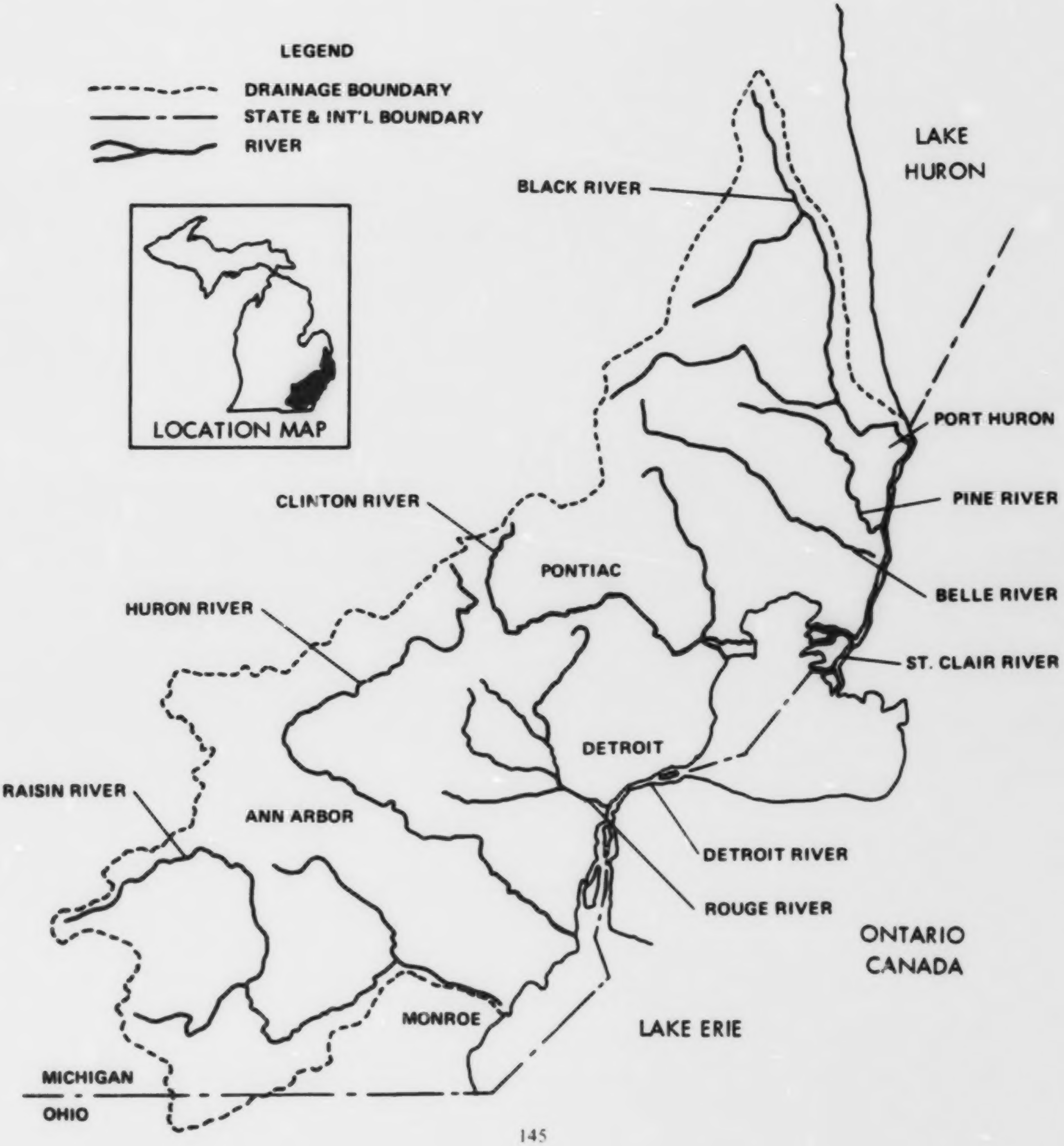
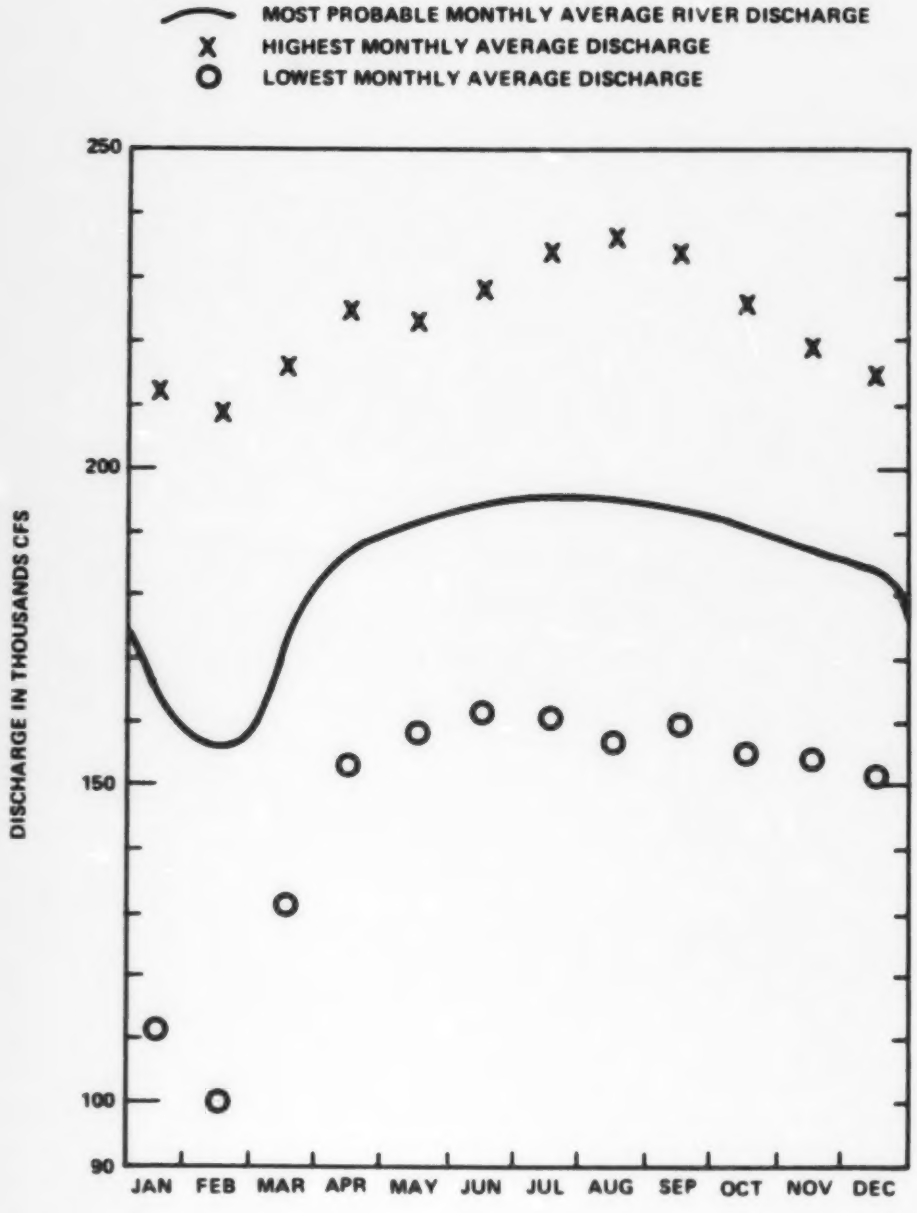

LEGEND
DRAINAGE BOUNDARY
STATE & INT'L BOUNDARY
RIVER
LOCATION MAP
LAKE HURON
BLACK RIVER
PORT HURON
PINE RIVER
CLINTON RIVER
PONTIAC
BELLE RIVER
HURON RIVER
ST. CLAIR RIVER
DETROIT
RAISIN RIVER
ANN ARBOR
DETROIT RIVER
ROUGE RIVER
ONTARIO CANADA
MONROE
LAKE ERIE
MICHIGAN
OHIO

Figure VII-2 TIME TREND

DETROIT AREA (RIVER)
FLOW
1936-1957 DATA



SOURCE: DROUGHT FLOW OF MICHIGAN STREAMS, DEPT. OF ENV. HEALTH, SCHOOL OF PUBLIC HEALTH UNIVERSITY OF MICHIGAN, 1960.

TABLE VII-1

DETROIT RIVER: WASTE SUMMARY, 1962-64*

Parameter	Industrial†	Municipal (lb./day)	Total
Iron	82,300	25,400	107,700
Copper	2,220	886	3,106
Cadmium	4	—	4
Nickel	51	1,610	1,661
Zinc	2,360	—	2,360
Lead	832	512	1,344
Chromium	318	—	318
Cyanides	1,030	55	1,085
Suspended solids	864,000	626,000	1,490,000
Ammonia	8,520	34,300	42,820
Total phosphate	10,000	152,000	162,000
Soluble phosphate	—	70,900	70,900
Chlorides	2,720,000	599,000	3,319,000
Acid	235,000	—	235,000
BOD,	170,000	525,000	695,000
Phenols	1,400	1,270	2,670

*Source: *Conference in the Matter of Pollution of the Navigable Waters of the Detroit River and Lake Eries and their Tributaries in the State of Michigan.* Second Session — June 15-18, 1965. U.S. Department of Health, Education, and Welfare.

†Includes industrial sources on Rouge River

TABLE VII-2

DETROIT AREA: PRINCIPAL DISCHARGERS TO RIVERS

River	Industrial (number of principal discharges)	Municipal
Huron	1	5
Raisin	3	2
Detroit	20	5
Rouge	5	0
St. Clair	5	4
Total	34	16

Metals data are not available for the Detroit River, and only five metals—cadmium, chromium, copper, nickel, and zinc—were measured in 1969-72 for the three southern tributaries. These data show no cadmium present; hexavalent chromium is present only in the Raisin River. The other metals are low or not present, with the Raisin River having the highest occurrence of the reported metals (Table VII-6).

The St. Clair River and Lake St. Clair have continuing problems associated with past discharges of mercury to the St. Clair River. Mercury is not evident in the water itself but has been found in the tissues of fish.

Total beta radiation was the only radioactivity parameter measured in the past 10 years. For the four tributaries having 10 years of data, noticeable decreases were observed in the past 5 years (Table VII-7).

Iron is included here even though it is not necessarily as harmful a substance as the pollutants previously discussed. Along the Detroit River shore the highest level (0.9 mg/l) occurs at mile 8.7, downstream from industrial discharges. Trends over the past 10 years are generally improving, except near the mouth of the river where the trend is worsening slightly. Over the 10 years the median iron concentrations entering the Detroit River from Lake St.

TABLE VII-3

DETROIT AREA RIVERS: DATA SOURCES AND LOCATIONS

Location (river miles from mouth)		No. of stations*	Sampling interval (no./mo.)	1963-67	1968-72
St. Clair River	(39.0)	2	April-Nov. (1-4)	FWPCA+	FWPCA
	(13.7)	3	" "	"	"
Detroit River	(30.8)	5	" "	"	MWRC‡
	(20.6)	6	" "	"	"
	(17.4)	6	" "	"	"
	(14.6)	9	" "	"	"
	(12.0)	5	" "	"	"
	(8.7)	6	" "	"	"
	(3.9)	7	" "	"	"
Tributaries		7	Jan-Dec. (1-2)	MWRC	"

*Only stations in U.S. waters.

+Data collected by EPA predecessor - Federal Water Pollution Control Administration.

‡Data collected by Michigan Water Resources Commission.

TABLE VII-4

ST. CLAIR AND DETROIT RIVERS: UPSTREAM WATER QUALITY, 1963-72

	St. Clair (RM 40)*			Detroit (RM 30.8)+	
	1963-67	1968-72		1963-67	1968-72
Temperature °C	9.0	8.0	(medians)	11.6	11.3
Turbidity JTU	25	2		25	10
Color PCU	3	0		—	215
DO mg/l	11.9	12.3		11.0	11.4
DO % saturation	101	100		102	103
BOD$_5$ mg/l	1.4	.6		.4	.4
COD mg/l				9	10
pH standard units	8.2	8.3		8.2	8.2
Total alkalinity mg/l	80	76		81	80
Conductivity µmhos		206			215
Dissolved solids mg/l	119	113		125	123
Suspended solids mg/l	39	12		39	7
Sulfates mg/l	11	17		15	15
Total phosphate P mg/l	.01	.02		.01	.02
Dissolved phosphate P mg/l	.01	.01		.01	.01
Ammonia mg/l	.1	.02		0	0
Total coliform (MFD) no./100ml	10	8		10	5

*Samples collected at Port Huron water supply intake.

+Samples collected at Detroit water supply intake.

TABLE VII-5

DETROIT AREA RIVERS: CYANIDE CONCENTRATIONS*

Location (river miles from mouth)	1966-67			1968-72	
	Median	85th Percentile	(mg/l)	Median	85th Percentile
Detroit River (30.8)+				0.01	0.01
(14.6)+	0.01	0.01		0.01	0.02
(12.0)+				0.01	0.02
(8.7)+	0.01	0.04		0.02	0.03
(3.9)+	0.01	0.02		0.01	0.02
Rouge River (near mouth)	0.05	0.10		0	0
Raisin River (near mouth)	0	0.25		0	0
Huron River (near mouth)	0	0		0	0

*Values reported as "less than" or "greater than" were excluded.

+Data aggregated for Detroit River cross-section stations.

TABLE VII-6

DETROIT RIVER: METALS IN TRIBUTARIES*

Metal (dissolved)	Years	Rouge River		Raisin River		Huron River	
		Median	85th Percentile	Median	85th Percentile	Median	85th Percentile
				(micrograms per liter)			
Cadmium	1969-72	0	0	0	0	0	0
Chromium	1969-71	0	0	20	60	0	0
Copper	1969-72	0	10	20	50	0	20
Nickel	1969-72	0	0	10	30	0	20
Zinc	1969-72	20	50	30	50	10	20

*Values reported as "less than" or "greater than" were excluded.

TABLE VII-7

DETROIT RIVER: RADIOACTIVITY IN TRIBUTARIES*

Location	1963-67			1968-72	
	Median	85th Percentile		Median	85th Percentile
			(gross beta count in pc/l)		
Rouge River	8	15			
Raisin River	13	26		10	14
Huron River	14	28		5	10
Clinton River	14	30		8	12
Belle River	16	28		6	8
Pine River	9	18			
Black River	9	23			

*Values reported as "less than" or "greater than" were excluded.

Clair remained constant at about 0.3 mg/l (Figure VII-3). The three tributaries show medians of 0.5 to 0.7 mg/l for the current 5 years with a noted improvement (2.0 to 0.7 mg/l) for the Rouge River, the only tributary sampled during the earlier 5 years.

Physical Modification

Temperatures of the tributaries have not changed over the 10 years, with the Rouge and Huron Rivers generally having 5-year medians of 14 to 16°C; the other rivers are 11 to 13°C. The St. Clair River is cooler, 8 to 9°C, and the water entering the Detroit River from Lake St. Clair is 2 to 3°C warmer. Along the Detroit River, temperatures increase due to waste and power discharges. Over the 30 miles along the shore, temperature increases are between 1 and 4°C, with the most noticeable change in the lower end probably due to the shallower water and more concentrated discharges (Figure VII-4).

Navigation and associated structures requiring maintenance and dredging introduce solids in the water, as do large industrial and municipal discharges. The only solids measurement made on a regular basis is suspended solids. Suspended solids improved over the 10 years; highest concentrations occur near the shore and in the lower river, showing the effect of waste discharges. The 5-year medians for suspended solids in 1968-72 are generally a third to half the values in the 1963-67 period. The lower portion of the river ranged between 14 and 22 mg/l along the shore, and the center portion for the entire river was 11 to 15 mg/l for 1968-72. Suspended solids along shore for the earlier 5 years were 22 to 46 mg/l and 23 to 24 mg/l in the center of the river.

Suspended solids for the tributaries range from 10 to 42 mg/l, with an improvement for 1968-72 as compared to the earlier 5-year period. While the suspended solids improved, the volatile portion of the suspended material remains unchanged, ranging between 6 and 15 mg/l.

Eutrophication Potential

Municipal and industrial activities discharge considerable amounts of ammonia, nitrates, phosphates, and organic nitrogen to the Detroit River and some tributaries. The water entering the Detroit River has low concentrations of these constituents, as does the St. Clair River. Noticeable increases occur in the lower 20 miles, particularly along the shore, while the center of the river shows little to no change.

Ammonia medians along the shore in the lower 20 miles for 1968-72 are higher (0.3-0.4 mg/l) from discharges, while the upper 10 miles and the center of the river remain very low (0-0.1 mg/l). The lower 8.7 miles indicate an improvement in ammonia concentrations in 1968-72 over 1963-67 (Figure VII-5).

Nitrates increase along the river more gradually than ammonia (0.08 to 0.28 mg/l), and there is a small increase (0.06 mg/l) in the center of the river. A possible explanation is that municipal waste discharges mix more thoroughly throughout the river than do industrial discharges along the shore. Limited data indicate an improvement in nitrates entering the river, while a worsening condition occurred at the mouth for the 10-year period.

Total and soluble phosphorus levels at the mouth of the Detroit River consistently decreased during 1968-72 (Table VII-8). In the past few years, phosphorus loadings entering Lake Erie have declined from 198,000 pounds per day to 74,000 pounds per day, according to the Michigan Water Resources Commission.

Total phosphorus increases noticeably below waste sources along the shore; there is also an increase in the center of the river, again pointing to the mixing of the municipal waste discharges. Downstream from combined sewer overflows, the extreme values for total phosphorus (85th percentile) are much higher than, for example, nitrate and ammonia (Figure VII-6). This indicates the possibility of intermittent discharges from combined sewers. Soluble phosphorus is 20 to 30 percent of total phosphorus, and in the lower river, it is 37 to 50 percent. Annual summaries by the Michigan Water Resources Commission confirm improved levels of ammonia and phosphorus entering Lake Erie, and worsening nitrates (Table VII-9).

Organic nitrogen data (available only for the 1963-67 period) indicate smaller changes along the river than for the phosphate measurements 0.07 to 0.09 mg/l in the upper river and 0.08-0.13 mg/l at the mouth.

Tributary data show higher levels of ammonia, nitrates, and phosphates than in the Detroit River. The Raisin, Huron, and Clinton Rivers have the highest 5-year medians, with the Clinton River showing marked improvements of

Figure VII-3. RIVER PROFILES

DETROIT AREA (RIVER)

TOTAL IRON

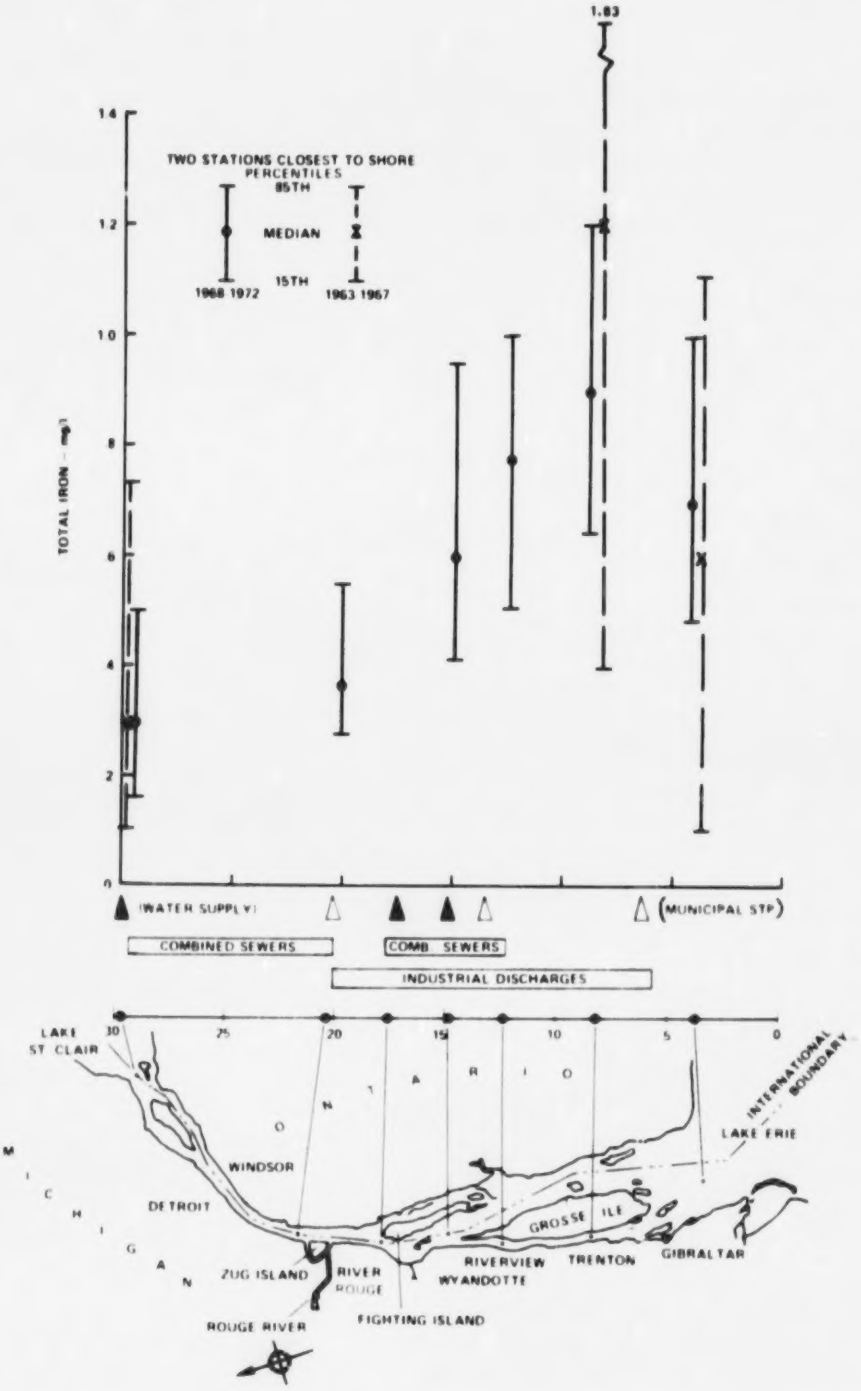


TABLE VII-8

DETROIT RIVER: TOTAL PHOSPHORUS AT RM 3.9 (1968-72)

Year	Distance from Michigan shore			
	2,500 feet	5,500 feet	7,500 feet	9,500 feet
	(medians - mg/l of phosphorus)			
1968	0.62	0.22	0.16	0.15
1969	0.58	0.21	0.13	0.08
1970	0.27	0.15	0.16	0.09
1971	0.22	0.15	0.09	0.06
1972	0.16	0.11	0.12	0.05

TABLE VII-9

DETROIT RIVER: AMMONIA, NITRATES, AND PHOSPHORUS AT RM 3.9 (1966-73)*

Year	Ammonia	Nitrates	Phosphorus (total)	Phosphorus (soluble)
	(mg/l)			
1966	0.270	0.080	—	0.309
1967	0.171	0.180	—	0.175
1968	0.134	0.190	0.186	0.072
1969	0.189	0.212	0.144	0.083
1970	0.167	0.227	0.133	0.062
1971	0.148	0.375	0.067	0.036
1972	0.142	0.275	0.079	0.029
1973	0.124	0.285	0.058	0.015

*Michigan Water Resources Commission Annual Report to International Joint Commission (average concentrations computed from 10 sampling stations across the river).

Figure VII-4 SEASONAL RIVER PROFILES

DETROIT AREA (RIVER)

WATER TEMPERATURE

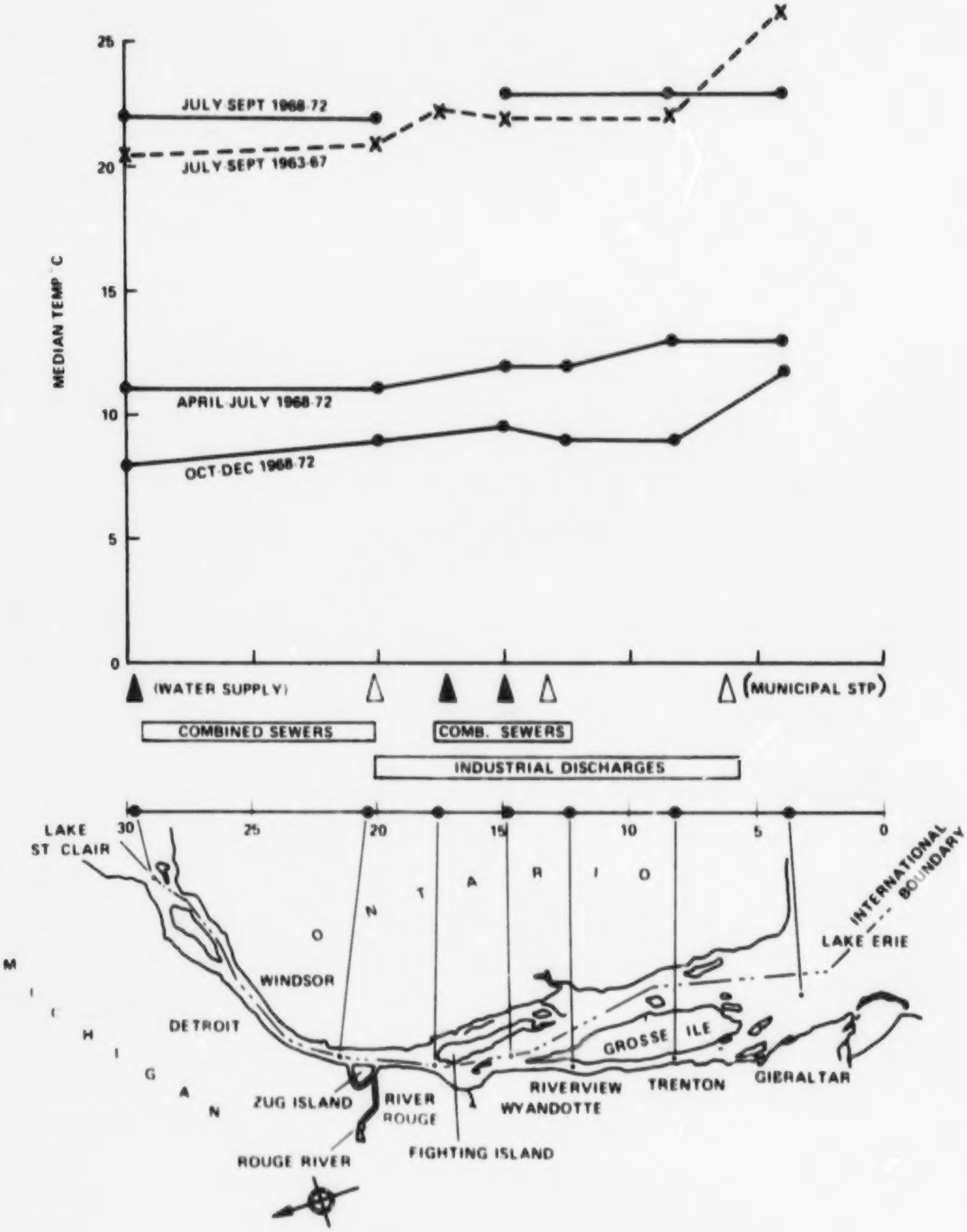


Figure VII-5 RIVER PROFILES

DETROIT AREA (RIVER)

AMMONIA

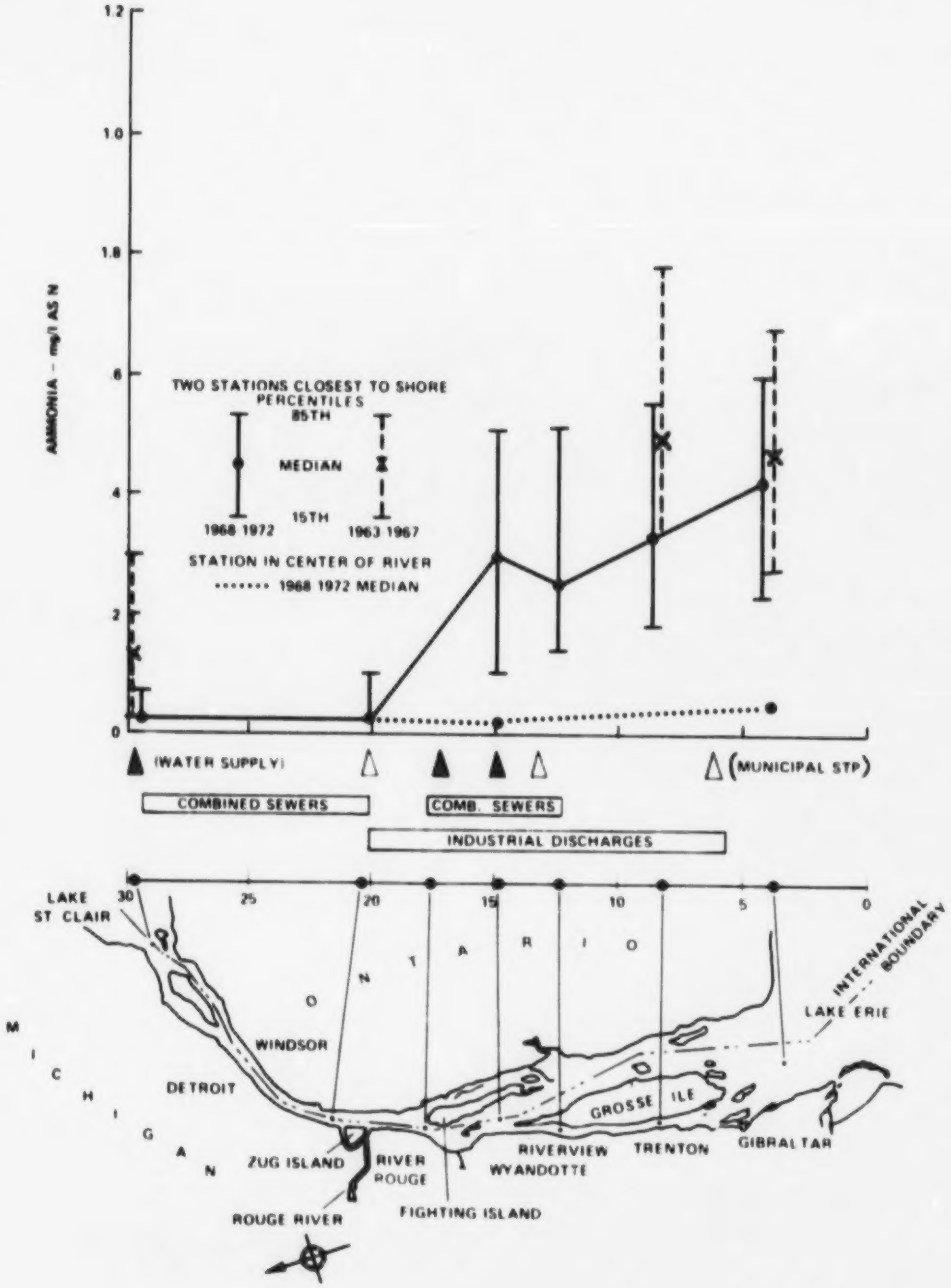
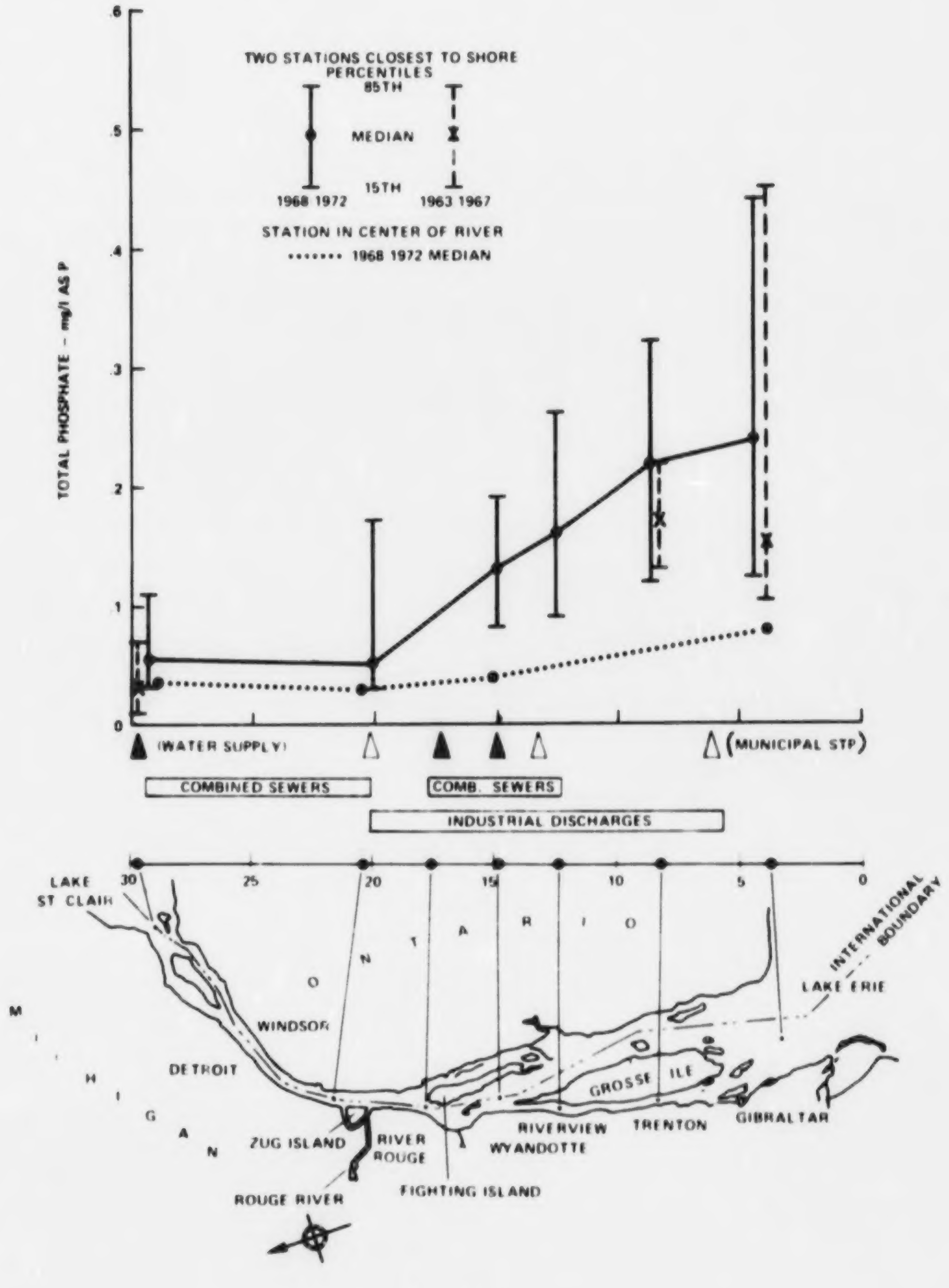


Figure VII-6 RIVER PROFILES

DETROIT AREA (RIVER)

TOTAL PHOSPHATE



nitrates, ammonia, and phosphates. The Raisin River, however, shows a worsening condition for nitrates in the 1968-72 period (Table VII-10).

Salinity, Acidity, and Alkalinity

The high chemical quality of water in Lake Huron, the St. Clair River and the upper end of the Detroit River changed little over the 10 years studied. As water passes through the Detroit River to Lake Erie, there are noticeable changes in chlorides and pH, the result of industrial discharges along the lower 20 miles.

Acid discharges along the shore at RM 17.4 produce a marked drop in pH, with the extreme pH (15th percentile) for 1963-67 of 5.9; pH unfortunately was not sampled in 1968-72. The downstream shoreline shows minor pH changes, with some improvement in the recent 5 years (Figure VII-7). The center of the river is not affected by acid discharges, and the total volume of water recovers to a generally neutral pH before entering Lake Erie.

Large industrial discharges along the lower Detroit River produce chloride levels near the shore that are twice as high as in the center of the river; the chloride levels are 60 percent lower in 1968-72 than they were in 1963-67, however (Figure VII-8). The cross sectional profile at RM 8.7 shows the significance of the improvement (Figure VII-9). The center of the river essentially remains unchanged, both over 10 years and along its 30 miles.

Tributary data show typical median levels for small streams—pH 7.9 to 8.2, alkalinity 85 to 188 mg/l, chlorides 18 to 78 mg/l, and dissolved solids 200 to 460 mg/l.

Oxygen Depletion

Low dissolved oxygen has not been a problem in the St. Clair or Detroit Rivers. In the lower Detroit River along the shore, reoxygenation is inhibited because the water becomes shallower and velocities decrease. The result is a 1 to 2 mg/l depression of dissolved oxygen at the mouth of the river during 1963-67, with an improvement in 1968-72 (Figures VII-10 and VII-11). BOD_5 levels are generally low throughout the river—usually 1 to 2 mg/l in the upper portion and 2 to 4 mg/l in the lower.

An entirely different condition exists in three of the seven tributaries. During 1963-67, low oxygen levels occurred in the Rouge and Clinton Rivers and fell to near zero in 15 percent of the samples from the Raisin River. Dissolved oxygen in all tributaries improved in the past 5 years, except that the 15th percentile worsened for the

TABLE VII-10

DETROIT AREA TRIBUTARIES: NITRATE, AMMONIA, AND PHOSPHATES LEVELS

Parameter	Years	Raisin	Huron	Rouge	Clinton	Belle	Pine	Black
				(medians in mg/l)				
Nitrate nitrogen	1963-67	0.2	0.5	0.25	1.2	0.2	0.25	0.2
	1968-72	0.8	0.4	0.2	0.5	0.2	0.2	0.2
Ammonia nitrogen	1963-67	0	0.1	0.4	3.2	0.1	0	0
	1968-72	0.1	0.3	0.25	1.2	0.1	0.1	0.1
Total phosphate (as phosphorus)	1968-72	0.3	0.3	0.1	0.64	0.16	0.1	0.06
Ortho phosphate (as phosphorus)	1963-67	0.1	0.32	0	1.60	0.03	0.07	0
	1968-72	0.12	0.17	0.03	0.48	0.05	0.05	0.02

Figure VII -7 RIVER PROFILES

DETROIT AREA (RIVER)

pH

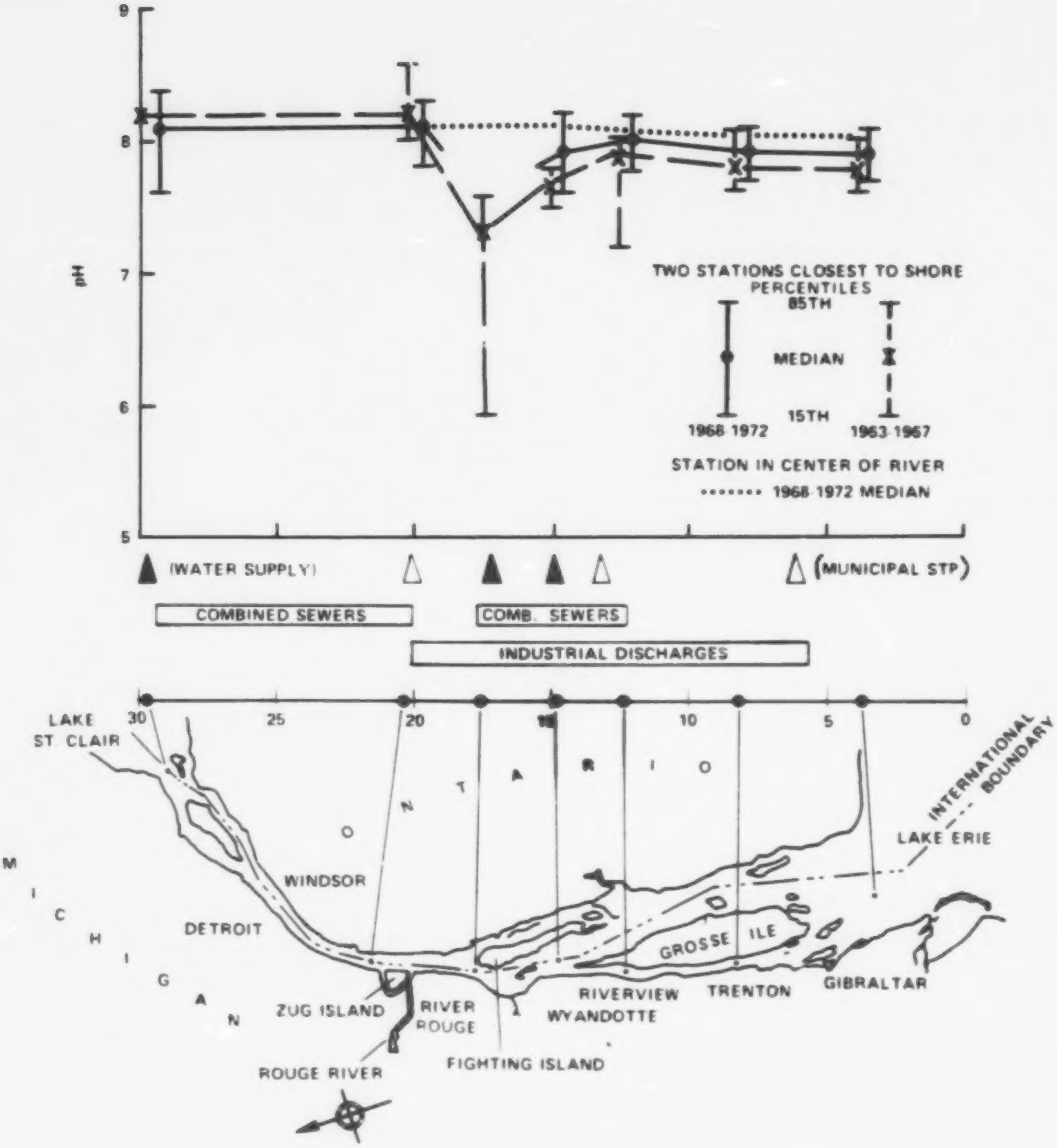


Figure VII-8. RIVER PROFILES

DETROIT AREA (RIVER)

CHLORIDE

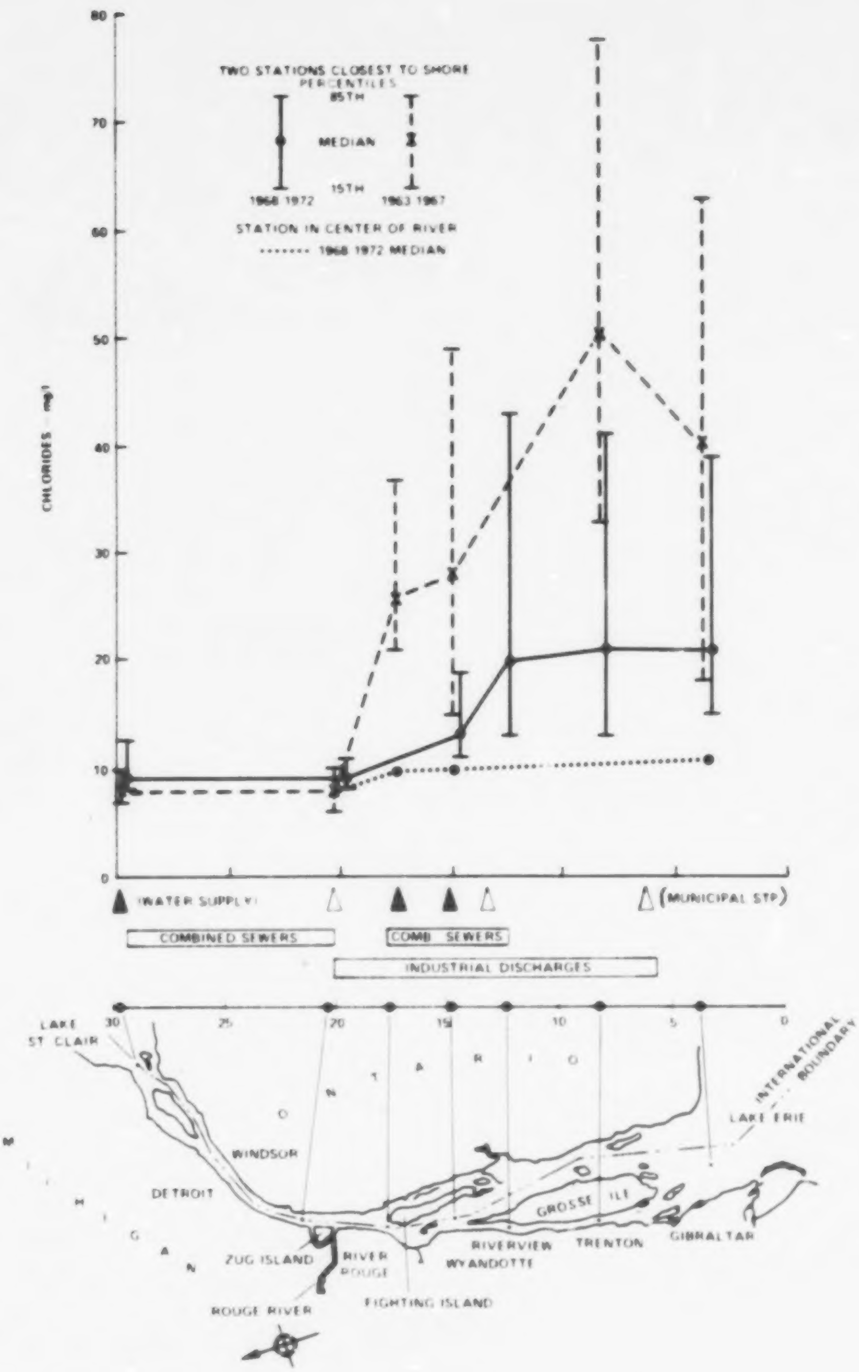


Figure VII-9 LATERAL RIVER PROFILES

DETROIT AREA (RIVER)

CHLORIDE

MILE 8.7

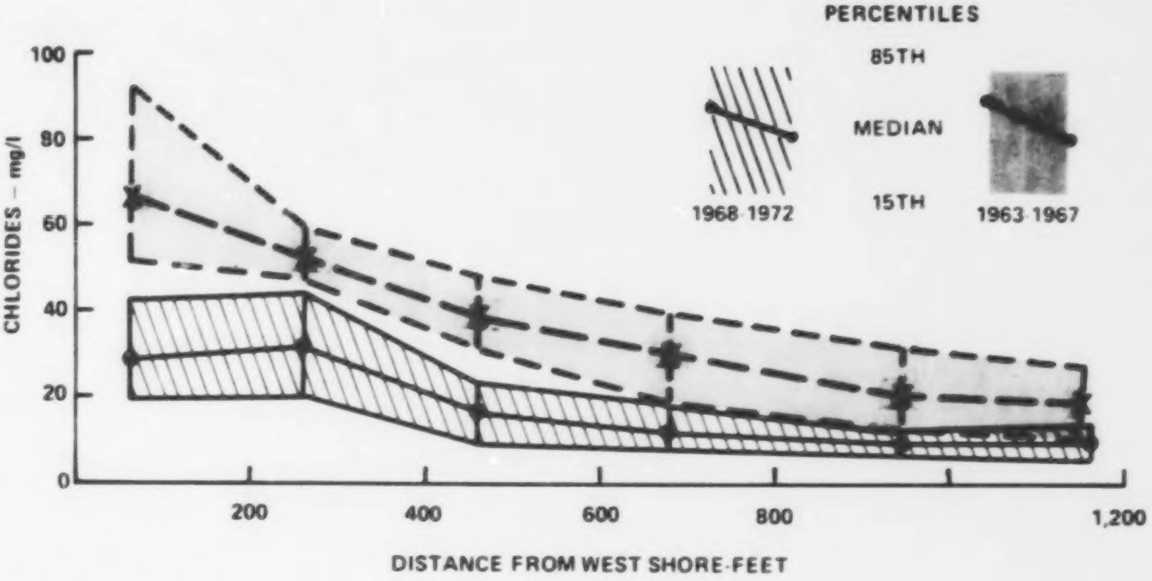


Figure VII-10. **RIVER PROFILES**

DETROIT AREA (RIVER)

DISSOLVED OXYGEN

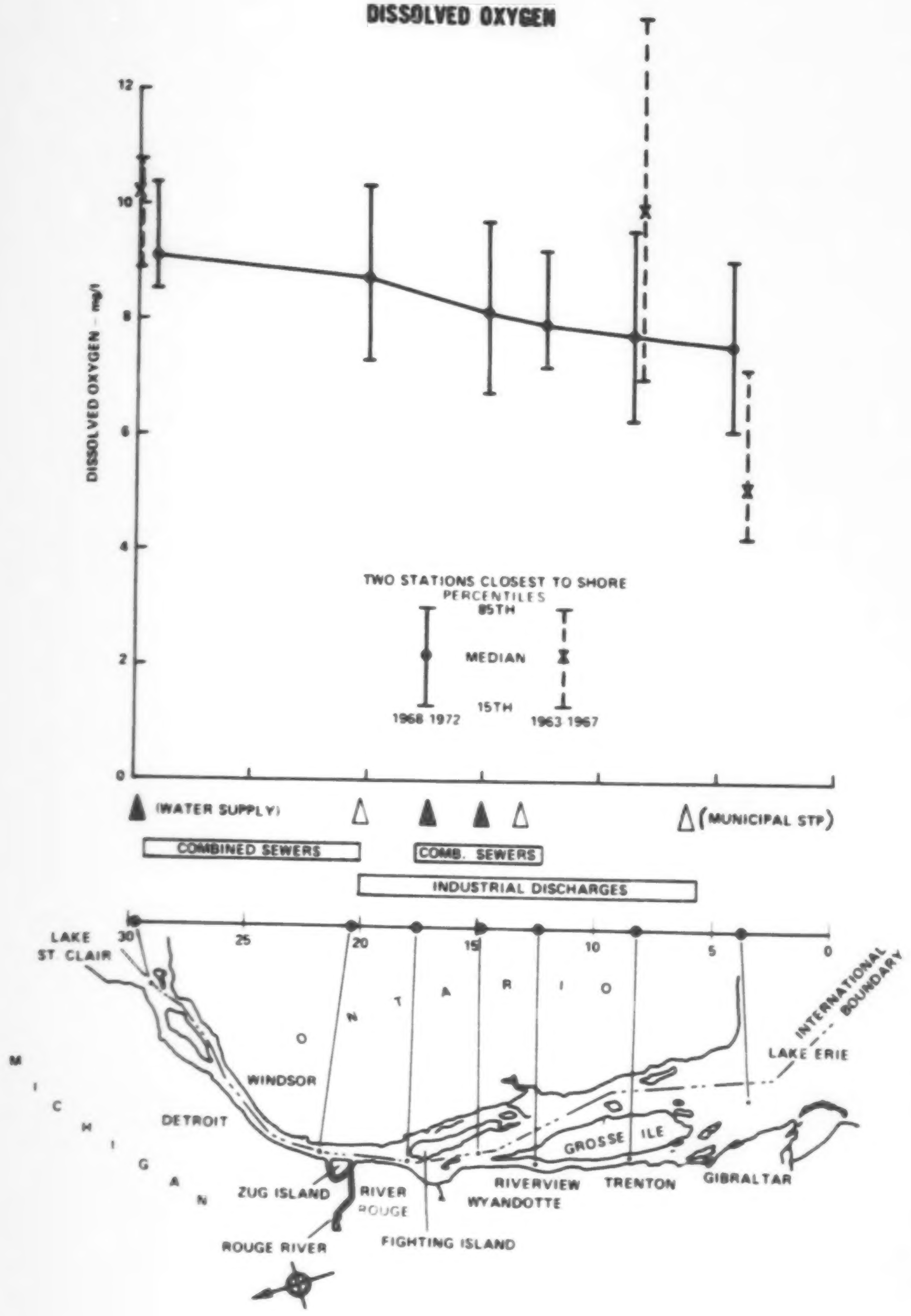
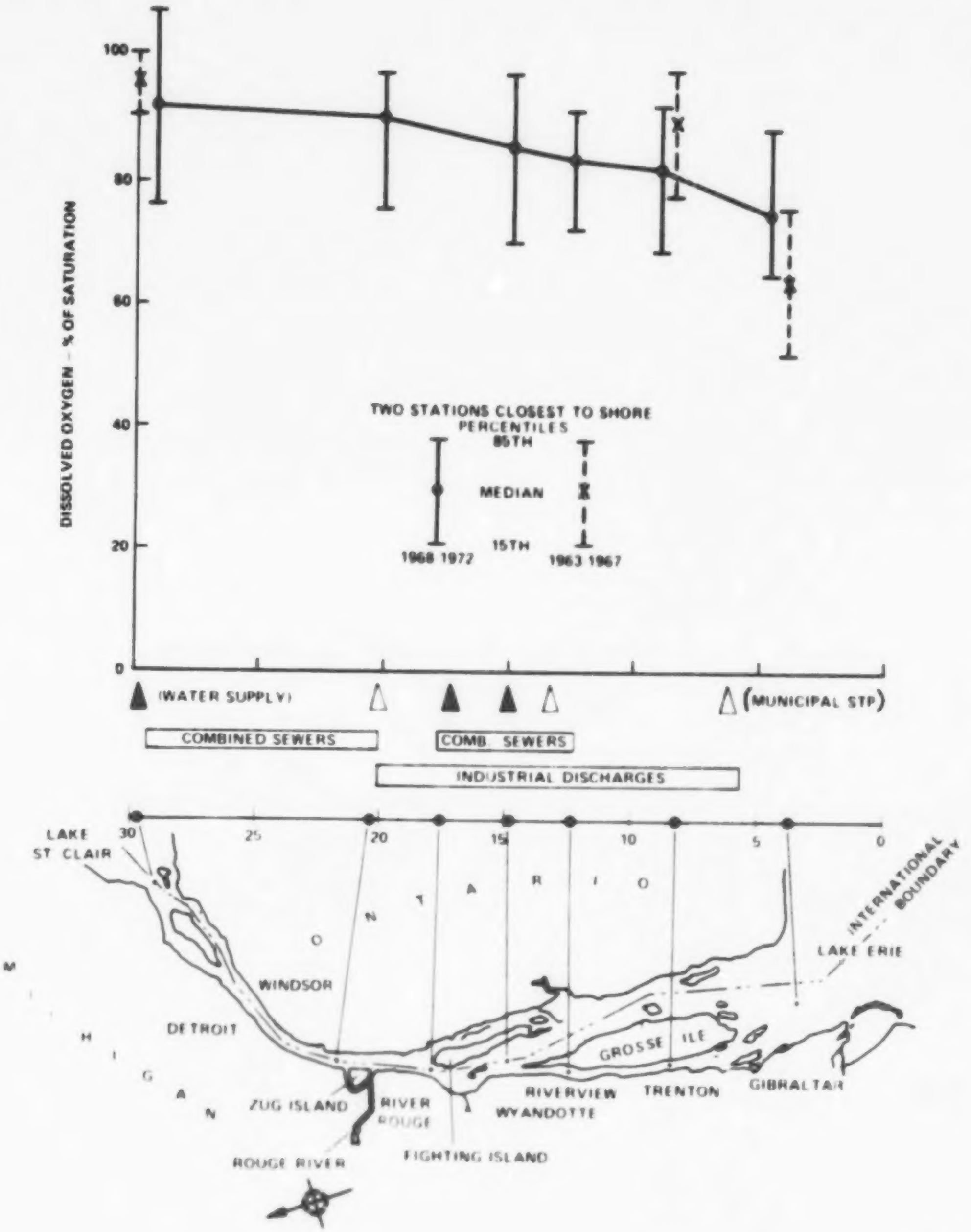


Figure VII-11. RIVER PROFILES

DETROIT AREA (RIVER)

DISSOLVED OXYGEN



Raisin River (Figures VII-12 and VII-13). As would be expected, BOD_5 levels in the tributaries improved along with dissolved oxygen levels.

Health Hazards and Aesthetic Degradation

Coliforms present in the Detroit River are from the combination of municipal waste treatment discharges in the lower 20 miles and combined sewer overflows along the upper 10 miles. The impact of overflows on the river depends on the intensity and duration of rainfall and the malfunction of combined sewers. Studies conducted in 1963-64, for example, indicate overflows could be expected 33 to 45 days per year when rainfall exceeds 0.2 to 0.3 inches. Average overflows were found to last about 8 hours, but longer periods of 24 hours and more also occur occasionally. Overflows during the survey period occurred 3 to 4 percent of the time. Stream quality records during a 9-month period (March-November) in 1963 showed that overflows from combined sewers affected water quality in the Detroit River during part or all of 88 days, (that is, 32 percent of the days), and this phenomenon occurred during the year of lowest accumulated rainfall. The 10 years of data show little change regarding total coliform densities: medians were slightly higher during 1968-72, and higher along shore than in the center of the river. The July-September interval was generally higher than the other 3-month periods. The upper 10 miles of the river had little change in the center, while along shore downstream from sewer overflows the medians and 85 percentiles showed a marked increase (Figure VII-14). Any improvement in combined sewer releases as a result of Detroit's sewer monitoring and remote control program may improve conditions observed in the past.

Fecal coliform measurements were not made for the entire 10-year period so trends could not be assessed. For 1971-72, fecal coliform densities were generally low throughout the river, with medians of 100 counts per 100 ml or less. The earlier 2-year period had medians between 500 and 1,100 counts per 100 ml in the lower river (Figure VII-15). The levels of coliform densities indicate a threat to water contact recreation and water supplies in the area, primarily during rainy periods. Total coliform data for the tributaries showed medians greater than 5,000 counts/100 ml for three rivers; conditions worsened in the Belle, Pine and Black Rivers (Table VII-11).

Phenols discharged primarily by industrial sources have been a problem in the lower 20 miles of the Detroit River. Data over the 10-year period show a marked improvement along shore and across the river (Figures VII-16 and VII-17). The St. Clair showed no change, with phenol levels similar to those at the upstream end of the Detroit River.

TABLE VII-11

DETROIT AREA TRIBUTARIES: COLIFORM COUNTS

		Total coliforms			Fecal coliforms		
Tributary	Years	15th Percentile	Median	85th Percentile	15th Percentile	Median	85th Percentile
				(no./100 ml)			
Raisin	1968-72	3,000	17,000	245,000	10	190	1,900
	1963-67	9,000	40,000	170,000			
Huron	1968-72	1,000	5,000	15,000	30	100	430
	1963-67	460	3,800	22,000			
Rouge	1968-72	1,000	10,000	250,000	60	300	3,400
	1963-67	910	7,500	9,400			
Clinton	1968-72	1,000	5,000	40,000	10	100	900
	1963-67	600	3,600	42,000			
Belle	1968-72	3,600	9,000	39,000	100	400	2,000
	1963-67	1,500	4,200	21,000			
Pine	1968-72	200	4,000	36,000	20	100	2,300
	1963-67	300	930	4,300			
Black	1968-72	200	3,300	25,000	10	100	700
	1963-67	300	910	4,100			

Figure VII-12. TIME TRENDS

DETROIT AREA (TRIBUTARIES)

DISSOLVED OXYGEN

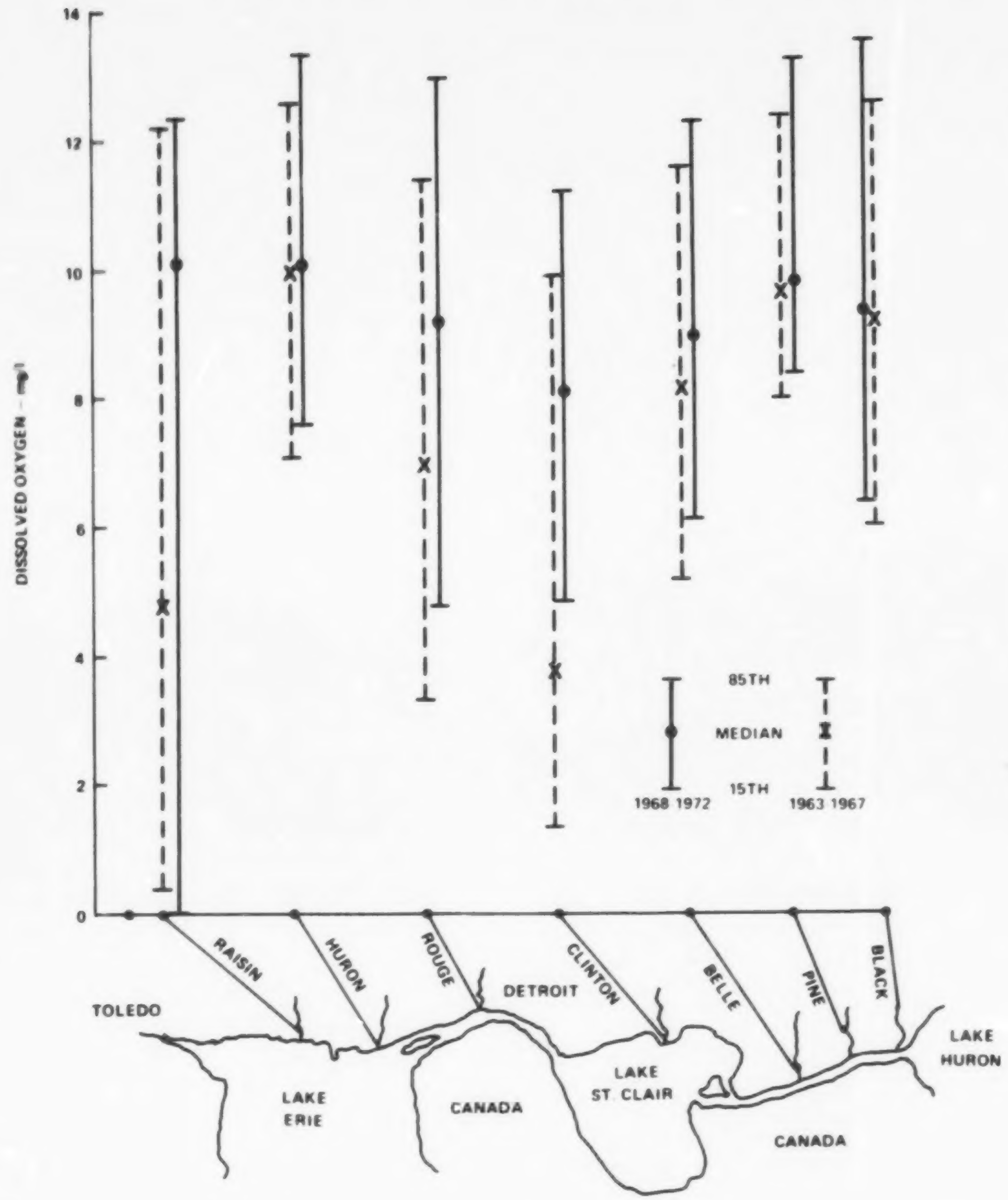


Figure VII-13. TIME TRENDS

DETROIT AREA (TRIBUTARIES)

DISSOLVED OXYGEN

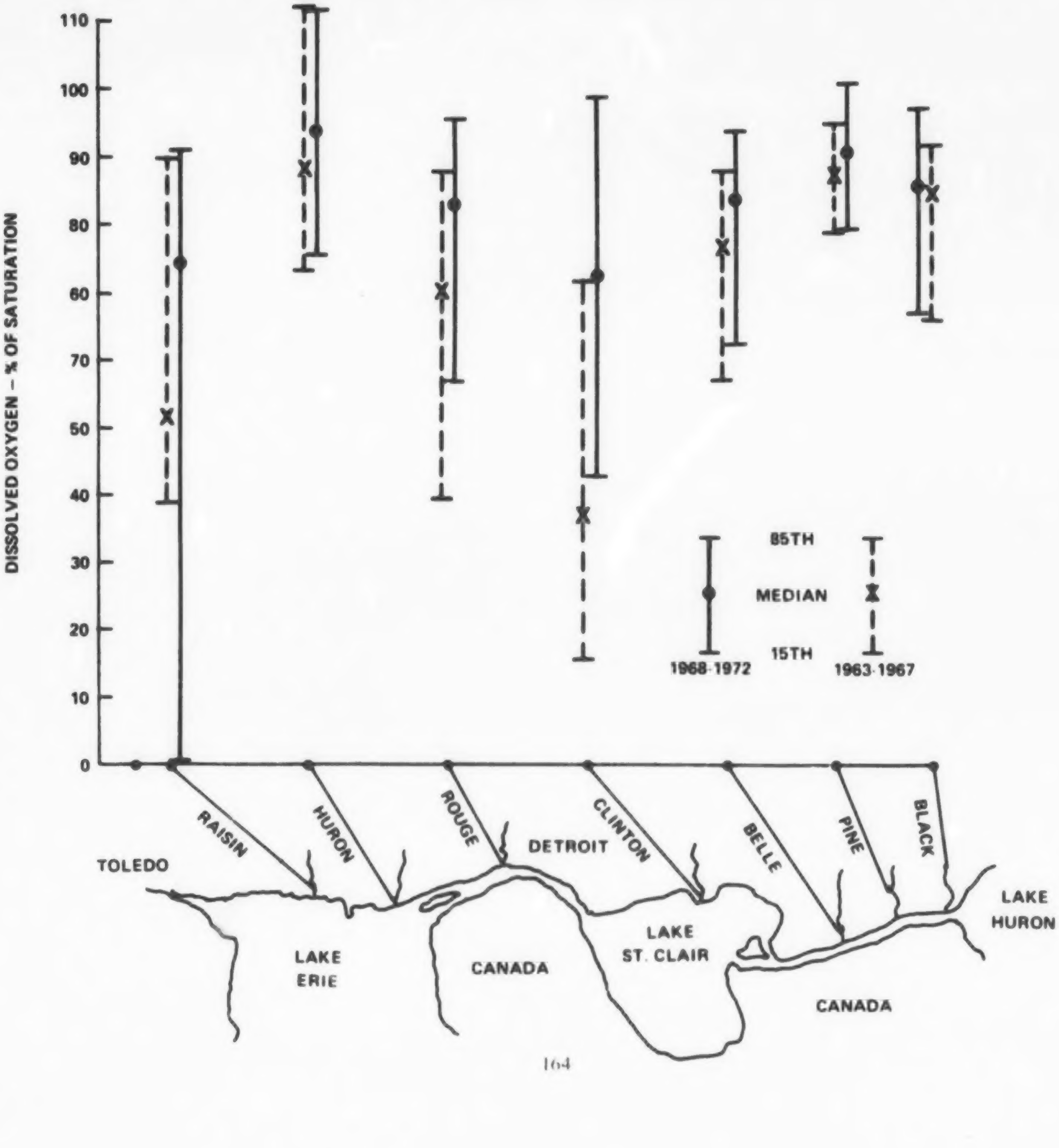


Figure VII-14 SEASONAL RIVER PROFILES

DETROIT AREA (RIVER)

TOTAL COLIFORMS

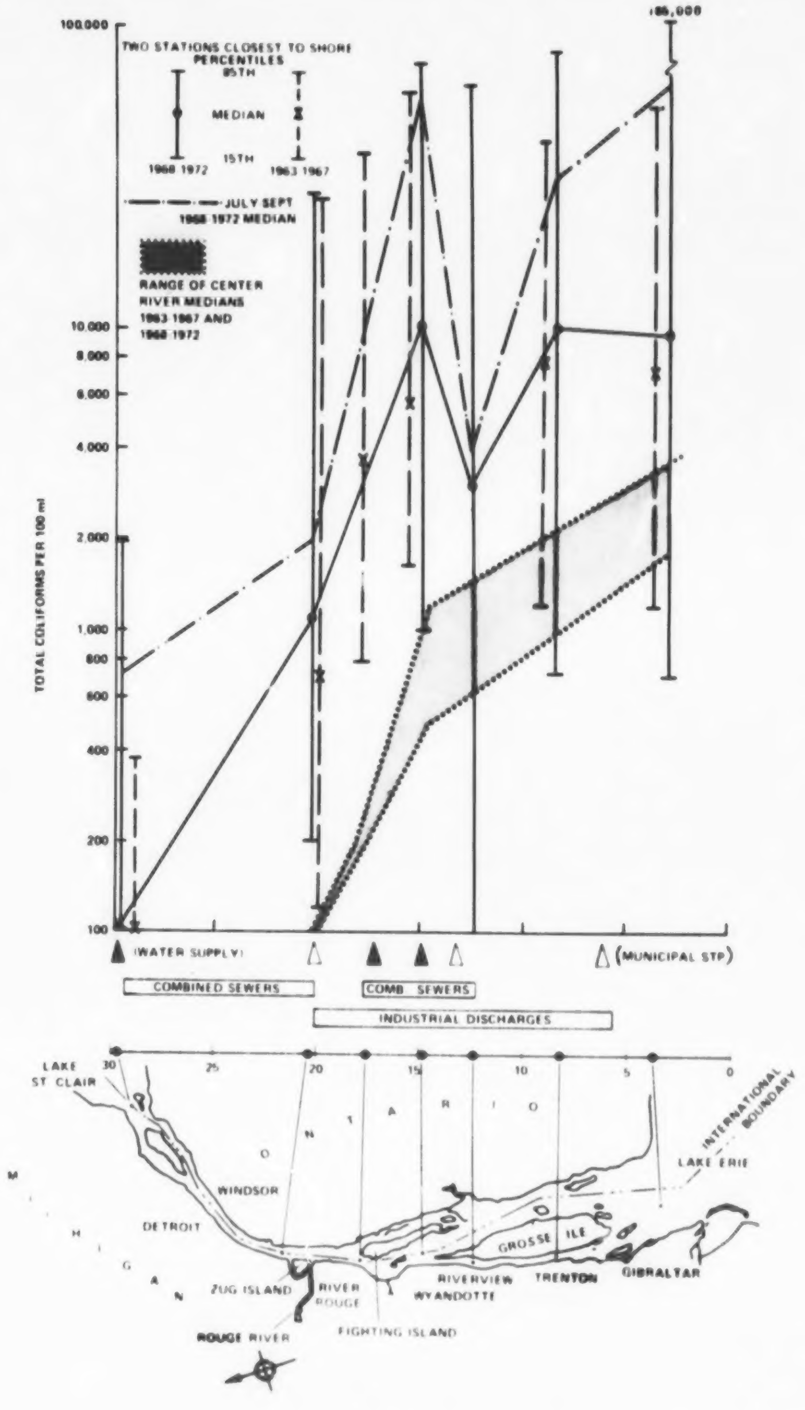


Figure VII-15. RIVER PROFILES

DETROIT AREA (RIVER)

FECAL COLIFORMS

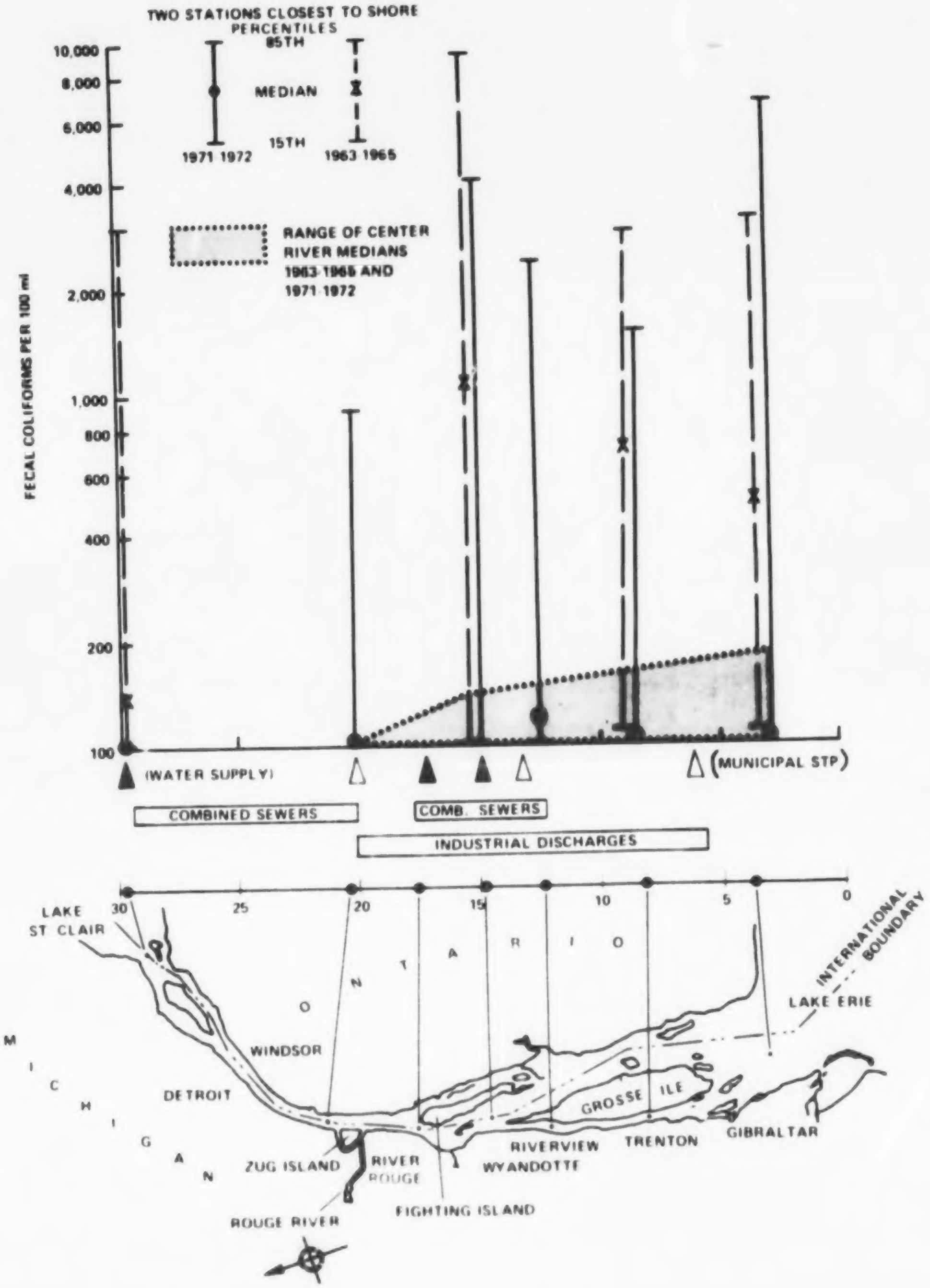


Figure VII-16 RIVER PROFILES

DETROIT AREA (RIVER)

PHENOLS

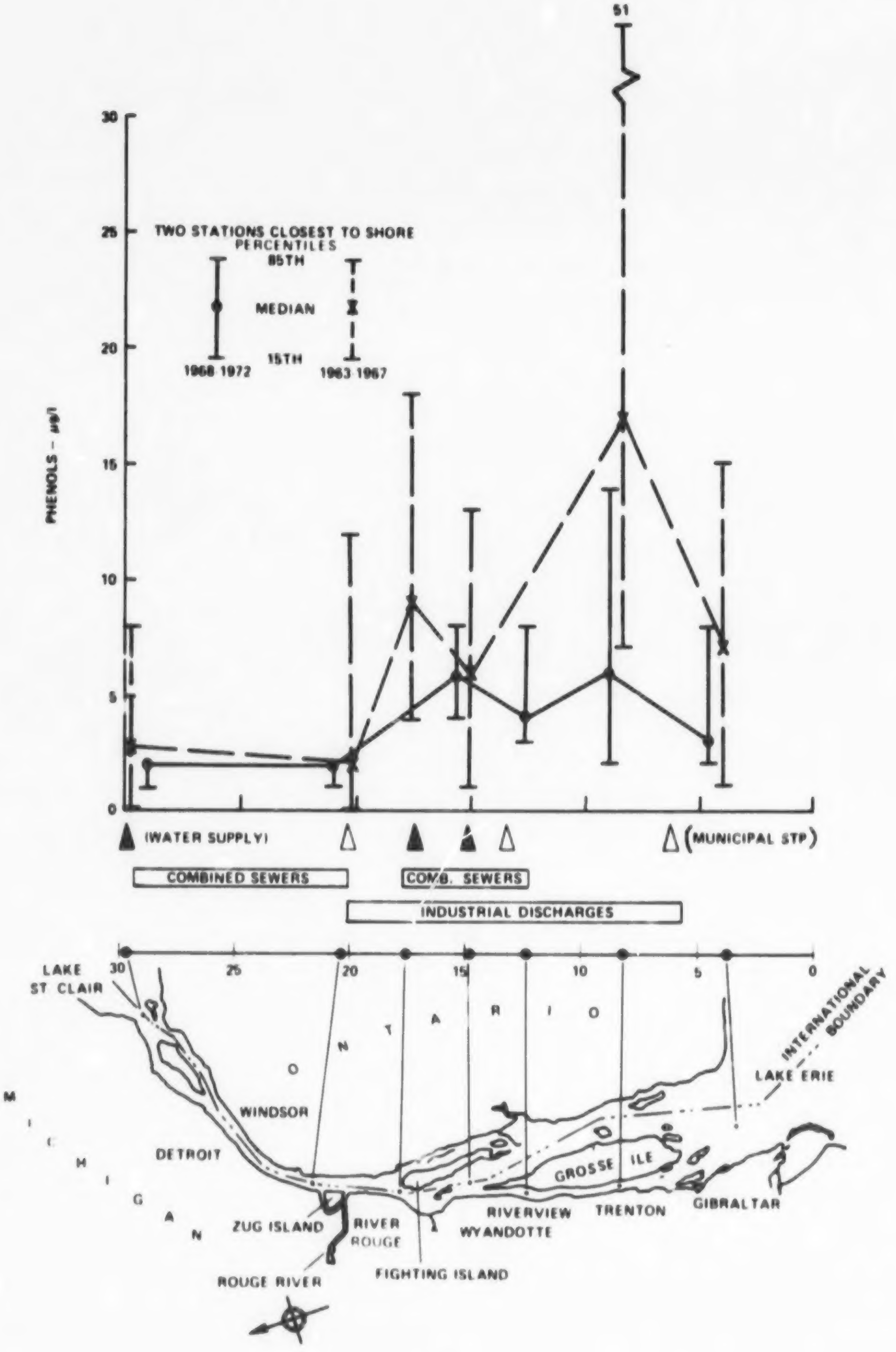
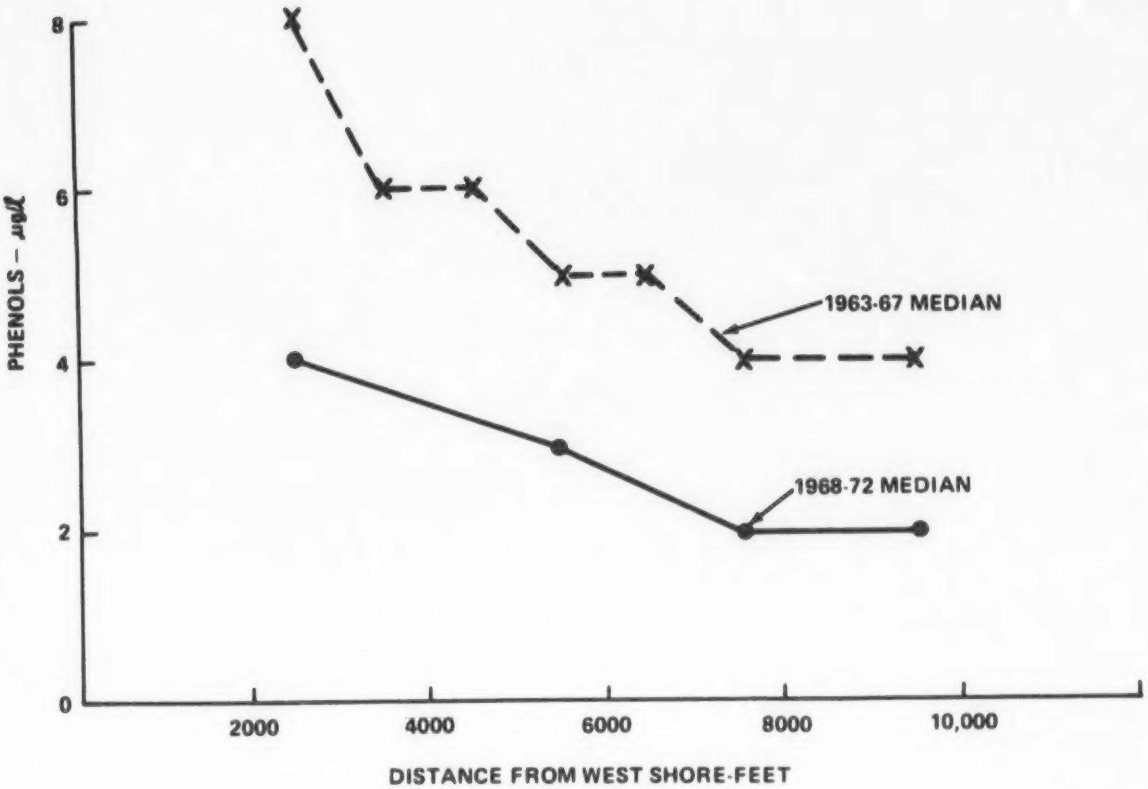


Figure VII-17 LATERAL RIVER PROFILES

DETROIT AREA (RIVER)

PHENOLS

MILE 3.9



VIII. COLUMBIA RIVER

The three segments of the Columbia River system—the Columbia itself and two major tributaries, the Willamette and the Snake—serve to illustrate the variety and complexity of water quality phenomena. All have experienced pollution in the past. Each has responded favorably to pollution abatement efforts, yet each is threatened by some variant of the pollution process.

The three rivers also serve to illustrate the limitations of the national approach to pollution abatement, which primarily concerns point-source pollution, with the seriousness of nonpoint pollution being taken into consideration only recently. Finally, the three rivers serve as evidence that the water pollution abatement effort is succeeding, for serious water quality problems have been eliminated in each river, and the aggregate quality of the rivers is indisputably superior to that of a decade ago.

The key pollutant measurements highlight conditions in the Columbia itself:

- *Harmful Substances.* Conditions toxic to fish due to supersaturation of gases begin in Canada and continue throughout the U.S. portion of the Columbia River. The supersaturation is induced during high flows by the turbulence of spillway releases from the 13 dams along the river. The gases are toxic to fish because they produce embolisms (gas bubbles in the bloodstream) similar to the "bends" experienced by divers. Radioactivity levels show a significant rise below the AEC Hanford Works, but monitoring indicates no beta radiation counts in excess of drinking water standards since the winter of 1964 and a continued drop since 1964. Specific radionuclides that concentrate in the food chain (zinc-65 and phosphorus-32) continue to be detected at measurable levels from Hanford to the mouth of the Columbia River, and in oysters taken on the Washington coast.

- *Physical Modification.* The general physical quality of the Columbia is good, but temperatures reach or exceed the established upper limit in August, and occasionally in July and September as well. Temperature levels are increased by the many dams and reservoirs, with documented peaks below the Hanford Works; temperature levels showed no observable overall change during the past 6 years. Other water quality measurements such as solids pose no problem.

- *Eutrophication Potential.* With the exception of slime growths *(Sphaerotilus natans)* in the lower river, the biological populations of the river are diverse and balanced, the opposite of eutrophic conditions. Although nitrate and phosphorus levels exceed desirable levels (particularly during high runoff periods), there are none of the usual symptoms of excess productivity such as noticeable variations in dissolved oxygen saturation. There are no trends to suggest increasing eutrophication.

- *Salinity, Acidity, and Alkalinity.* The Columbia approaches the ideal for fresh waters in terms of the broad chemical indicators (pH and conductivity) of acidity and salinity.

- *Oxygen Depletion.* Dissolved oxygen levels are quite satisfactory, with no trend over the last 6 years. The natural flow, velocity, and surface area of the river seem to be sufficient to provide concentrations that are very close to theoretical saturation limits.

- *Health Hazards and Aesthetic Degradation.* From limited data, total and fecal coliform levels are very low and indicate no threat to water contact and drinking water uses.

GENERAL PHYSICAL DESCRIPTION

The Columbia River, third in volume of flow only to the Mississippi among rivers of North America, drains 259,000 square miles—220,000 in the United States—and traces a length of 745 miles from the Canadian border to its mouth. Mean annual discharge is about 170,000 cfs, equal to more than 120 million acre-feet or 40,100 billion gallons a year. Figure VIII-1 shows the Columbia River drainage area and mainstem dams. Figure VIII-2 shows monthly discharge patterns at two locations.

The Columbia generates enormous velocity and energy as it drops 2,650 feet in 1,243 miles. That energy has been harnessed by a series of hydroelectric dams that have turned the part of the Columbia in the United States into a series of pools. Compared to smaller and less regulated rivers, streamflow is extraordinarily constant from month to month, primarily a result of snowmelt in the northern Rockies; however, the altered flow pattern of irrigation-regulated eastern tributaries and flood-controlled tributaries arising in the Cascades somewhat modifies the natural pattern of snowmelt flooding. Mean minimum month streamflow at Bonneville Dam is 70 percent of mean month flow, 45 percent of mean maximum month flow. Low flows in the upper river occur in the fourth quarter, when precipitation occurs as snow that remains on the ground and when reservoirs are storing for the irrigation season. On the lower river, the heavy winter rains and summer drought characteristic of the Pacific rim shift the period of low flows to late summer. High flows are concentrated in May and June.

POLLUTION PROBLEMS AND SOURCES

So great are the flow and velocity of the Columbia that the U.S. Geological Survey calculated (1967) that all of the people and industry of the United States could be concentrated along its banks without causing water pollution. Theoretically interesting, those calculations missed the mark by equating water pollution with the quantity of waste discharges, for complex biological and physical reactions have resulted in three indisputable periods of pollution on the Columbia over the last four decades. By far the worst of these is present today.

In 1939, the President's Advisory Committee on Water Pollution found that the Columbia below the mouth of the Willamette was "seriously polluted"—a dubious distinction it shared with only the Willamette River and Los Angeles area coastal waters among all waters west of the Continental Divide. That situation, the result of sewage bacteria and their regrowth upon nutrients provided by pulp mill wastes, persisted through the 1950's.

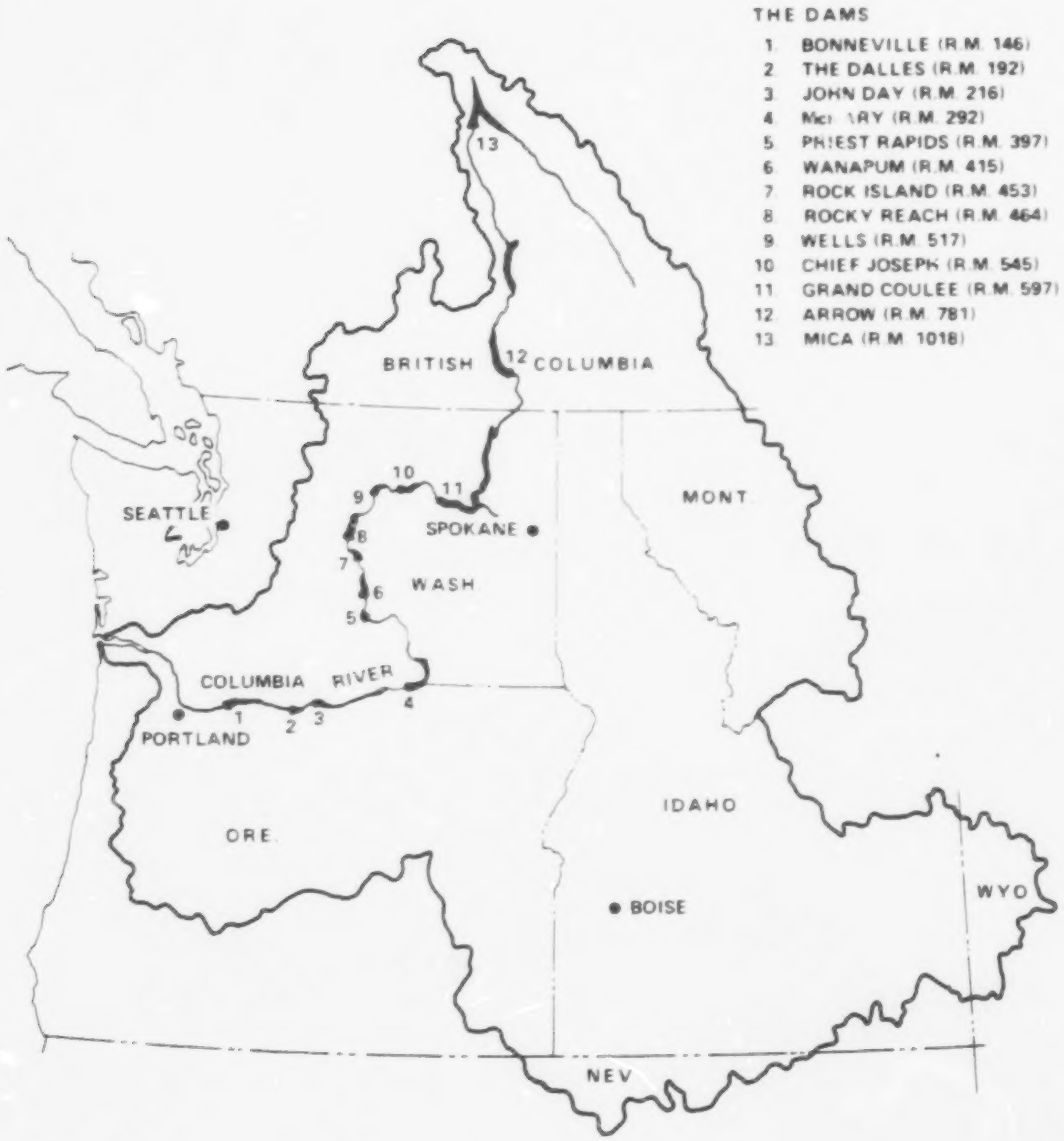
As the sewage bacterial problem receded, a new problem appeared in the lower river. Slime growths *(Sphaerotilus natans)* associated with pulp and paper mill wastes became an aesthetic affront and a nuisance to recreational and commercial fishermen. While the exact cause of the growths remains a question, extension of pulp mill waste treatment had practically eliminated them by the summer of 1972.

But by that time a far more serious form of pollution—gas supersaturation—had appeared in the Columbia and on many of its tributaries. The saturation problem is pervasive: It is present in the river as it crosses the Canadian border and persists to the mouth. And it is perennial. The spring flood entrains and dissolves atmospheric gases as it cascades over the spillways of the numerous dams in the Columbia system, producing gas supersaturation, which is toxic to most fish species. The number of dams has increased to the point that the succession of spillway discharges accompanying high flow makes it impossible for the stream to reach equilibrium until flows recede.

Dam-induced gas supersaturation must be among the most difficult environmental problems facing the United States. While not beyond the reach of existing technology, it cannot be mitigated by applying the point-source control techniques that are the basis of U.S. water pollution control law. Complicating the problem are its international features, and the tradeoff it forces between producing electric power and protecting fish.

Point discharges of waste, while generally a minor influence on the quality of the Columbia, have twice been implicated in the pollution of the lower river. The direct effects of the discharges were slight, but biological reactions created discernible pollution.

Figure VIII-1 AREA MAP
COLUMBIA RIVER
DRAINAGE AREA AND MAINSTEM DAMS


BRITISH COLUMBIA
MONT
WASH
SEATTLE
SPOKANE
COLUMBIA RIVER
PORTLAND
ORE.
IDAHO
BOISE
WYO
NEV
1
2
3
4
5
6
7
8
9
10
11
12
13

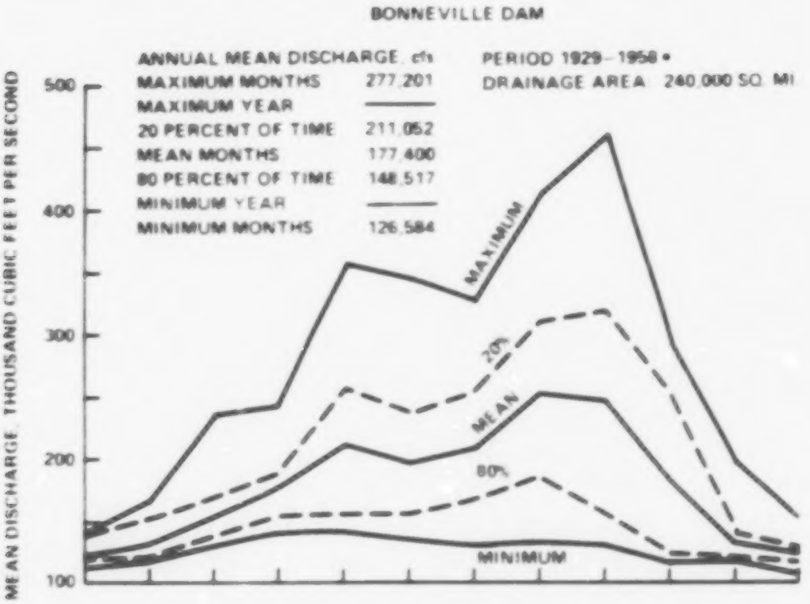
THE DAMS

1. BONNEVILLE (R.M. 146)
2. THE DALLES (R.M. 192)
3. JOHN DAY (R.M. 216)
4. McNARY (R.M. 292)
5. PRIEST RAPIDS (R.M. 397)
6. WANAPUM (R.M. 415)
7. ROCK ISLAND (R.M. 453)
8. ROCKY REACH (R.M. 464)
9. WELLS (R.M. 517)
10. CHIEF JOSEPH (R.M. 545)
11. GRAND COULEE (R.M. 597)
12. ARROW (R.M. 781)
13. MICA (R.M. 1018)

Figure VIII-2 TIME TRENDS AT RIVER MILEPOINTS

COLUMBIA RIVER

MEAN MONTHLY DISCHARGE



• ADJUSTED FOR 1970 FLOW REGULATION CONDITIONS

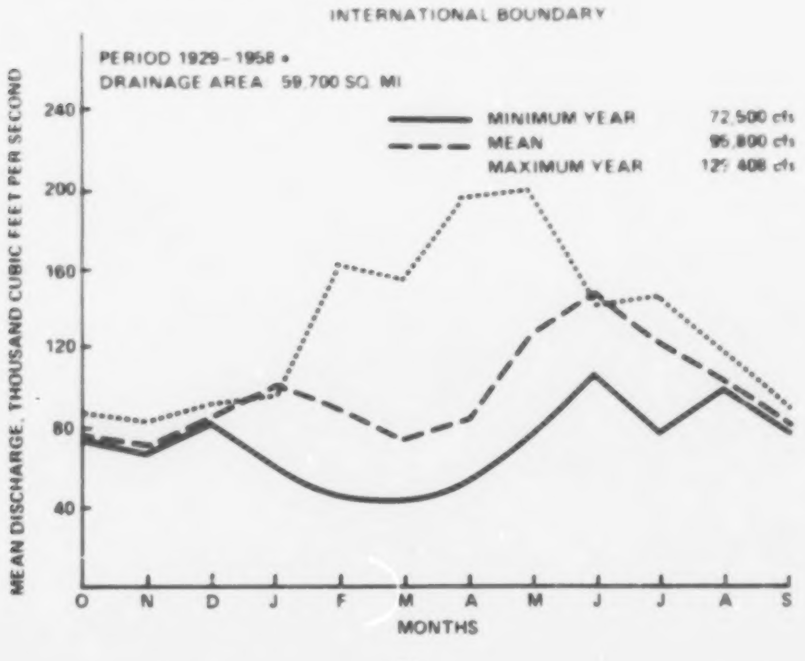


TABLE VIII 1

COLUMBIA RIVER: POINT WASTE DISCHARGES (1972-73)

Discharger	River mile	Treatment	Flow (mgd)*		BOD$_5$ (lb/day)		Phosphorus (lb/day)		Nitrates (lb/day)	
			Sewage	Industry	Sewage	Industry	Sewage	Industry	Sewage	Industry
Warrenton	3.3	Secondary	0.17		21		12		28	
Astoria	13.7	None	1.10		1,870		105		271	
Astoria–Tongue Point	17.8	Secondary	0.14		26		15		39	
Tongue Point	18.2	None	0.12		204		12		32	
Crown Zellerbach Corp	39.8	Chemical recovery–primary		33.9		68,920		144		14
Reynolds Metals Co	63.1	Recycling		16.3		883		158		190
Weyerhaeuser Co	66.0	Chemical recovery–primary		117.8		181,168		1		
Cowlitz County	66.0	None	8.10		1,377		776		1,998	
Longview: Westside	66.0	Secondary	1.40		21		12		32	
Eastside	66.0	Primary	4.80		39,990		310		863	
Rainier	67.4	Primary	0.18		282		11		30	
Longview Fibre	68.1	Chemical recovery–primary		61.4		107,000		243		431
Kalama	74.8	Primary	0.30		173		30		27	
Virginia Chemicals	74.9	Nonoverflow lagoon		3.0		125		3		7
Kalama Chemicals	74.9	None–cooling water		13.0		6,071				12
Reichold Chemicals	82.1	API separator (cooling water)		21.0		700		9		44
St. Helens	86.0	Primary	1.32		661		47		122	
Boise Cascade Corp	87.6	Chemical recovery–primary & secondary		32.2		44,000		113		64
Portland: Inverness	101.0	Primary	0.58		342		27		24	
Columbia Blvd	101.0	Primary (secondary under construction)	70.50		66,520		3,075		9,316	
Great Western Malting	105.1	None–cooling water		6.0		2,404		38		3
FMC Corp	106.0	None–cooling water		11.7		486		55		158
Northwest Packing Co	106.0	None–cooling water		1.2		260		1		5
Boise Cascade Corp	106.0	Primary		13.0		10,300		29		164
Alcoa	106.0	Primary		17.0				2		100
Vancouver: Eastside	106.5	Secondary	0.40		451		163		419	
Westside	106.5	Primary	5.30		13,637		346		817	
Gresham	118.0	Secondary	3.30		5,177		163		419	
Wood Village	120.0	Primary	0.17		31		10		27	
Crown Zellerbach Corp	120.1	Chemical recovery–primary		107.8		172,030		418		
Reynolds Metals Co	120.5	Chemical precipitation & recycling		3.8		81		3		
Washougal	121.3	Secondary	0.40		46		27		69	
Below Bonneville			99.08	675.1	150,778	594,628	5,121	1,419	14,330	1,192

TABLE VIII-1 (Continued)
COLUMBIA RIVER POINT WASTE DISCHARGES (1972-73)

Discharger	River mile	Treatment	Flow (m.g.d.)*		BOD₅ (lb./day)		Phosphorus (lb./day)		Nitrates (lb./day)	
			Sewage	Industry	Sewage	Industry	Sewage	Industry	Sewage	Industry
Stevenson	150.5	Secondary	1.20		17		10		25	
Broughton Lumber	168.0	NA		19.0		72		37		1
Hood River	169.4	Primary	1.30		1,693		48		133	
White Salmon	170.0	Primary	0.17		189		15		41	
The Dalles	189.3	Primary	2.20		2,096		111		308	
Harvey Aluminum	189.3	Chemical precipitation		20.0		1,670		10		25
Cherry Growers	189.3	NA		40.0		1,369				
St. Regis Paper	194.1	NA		16.0		801		13		27
Harvey Aluminum	210.1	Chemical precipitation		13.0		610		110		10
Boise Cascade Corp	315.0	Chemical recovery - primary		11.0		22,593		43		33
Kennewick	328.4	Primary	4.30		6,849		117		380	
Phillips Pacific Chemical	328.4	None		23.9		216				11
Chevron Chemical	328.4	None		10.0		507		38		218
McNary Pool-Bonneville			9.17	154.9	10,844	27,831	321	251	887	325
Pasco	330.0	Secondary	2.39		392		134		344	
AEC Hanford Works	380.0	Isolation of radioactive liquids		289.7†				1		
Washington Public Power (Hanford)	380.0	None - cooling water		1,710.0						
Foote Mineral	452.4	NA		2.5		18†		[illegible]		13
Alcoa	458.2	Chemical precipitation		21.2†		1,050†		10†		90†
Keyes Fibre	465.5	Primary & recycling		1.0		67				67
Wenatchee	465.5	Primary	1.93		2,113		163		454	
Patheros	524.4	Secondary	0.11		76		5		13	
Brewster	530.0	Secondary	0.15		24		11		29	
Bridgeport	543.7	Secondary	0.16		102		10		25	
Coulee Dam	596.0	Primary	0.22		303		12		31	
Douglas County	NA	Primary	0.40		500		33		84	
Canadian Border to McNary Pool			5.36	2,024.4	3,510	1,135†	368	11	636	170
Basin total			113.61	2,654.4	145,132	623,596	5,810	1,683	16,053	1,687

*Million gallons per day

†Estimated

Significant waste discharges have been identified at 56 points (Table VIII-1). These include 29 public sewage systems, seven pulp or paper mills, six aluminum reduction plants, seven chemicals plants, two lumber mills, three food processing plants (the majority of food processors, like fabricating plants, discharge to public sewage systems), the AEC's Hanford plutonium processing works, and a nuclear-fueled electric generating plant. (Two other nuclear electric plants will come on line during the 1970's.) Potential pollutants discharged by these sources include the chlorine residual of sewage disinfection, organic materials, living organisms (bacteria and viruses), nutrients, heat, fluorides, radioactivity, inorganic matter, and solids.

No source or location stands out when all potential pollutants are considered. Taking both the power company and the AEC installation, Hanford discharges about 2 billion gallons of heated water per day to the Columbia, about 72 percent of all point discharges (Table VIII-2). Municipal sewage accounts for about 91 percent of the nitrogen and 77 percent of the phosphorus from point sources. Pulp and paper wastes account for close to 80 percent of BOD_5 and solids from point sources. Fluorides are contributed by the six aluminum plants, and bacteria by sewage discharges, urban runoff, and industrial waste treatment lagoons. Radioactivity arises entirely from the Hanford complex. With the exception of heat and radioactivity, discharges are concentrated near population and industrial centers along the lower river below Bonneville Dam.

TABLE VIII-2

COLUMBIA RIVER: DISTRIBUTION OF POINT WASTE DISCHARGES BY SOURCE (1972-73)

Waste source	Flow		BOD_5		Phosphorus		Nitrates	
	m.g.d.*	%	lb./day	%	lb./day	%	lb./day	%
Municipalities	113.6	4.1	145,132	18.9	5,800	77.3	16,372	90.7
(Portland)	(71.1)	(2.6)	(66,962)	(8.7)	(3,102)	(41.3)	(9,340)	(51.7)
Pulp & paper	395.1	14.3	606,211	78.9	993	13.2	706	3.9
Chemicals	85.3	3.1	7,418	1.0	107	1.4	463	2.6
Aluminum reduction	91.3	3.3	4,300†	0.6	493†	6.6	415†	2.3
Washington Public Power	1,710.0	61.8						
AEC Hanford Works	289.5	10.5			1			
Food processing	47.2	1.7	4,033	0.5	39	0.5	8	
Other	36.0	1.3	1,634	0.2	75	1.0	95	0.5
Total	2,768.0		768,728		7,508		18,059	
Above Bonneville Dam	2,193.8	79.3	43,322	5.6	978	13.0	2,337	12.9
Below Bonneville Dam	574.2	20.7	725,406	94.4	6,530	87.0	15,722	87.1

*Million gallons per day

†Presumably attributable to sanitary wastes. Aluminum reduction is significant to water quality primarily in terms of fluorides, suspended solids, and heat, rather than oxygen demand and nutrients.

Erosion—largely a result of natural forces but exacerbated by agriculture, construction, silviculture, and urbanization—also affects the river, adding millions of tons of materials each year. Solar radiation absorbed by the broad surfaces of reservoirs and the resulting temperature stratification represent enormous shifts in the energy regimen of the stream. Thus, the naturally fertile river receives and nurtures additional untold numbers of soil and plant organisms from erosion and solar radiation.

But those natural and human-influenced conditions can scarcely be considered sources of pollution. The river's volume and velocity have proved to be great enough to maintain a quality that rarely drops below the very high legal criteria set by the States of Oregon and Washington. A pollutant that exercises no discernible influence on the Columbia, however, may significantly degrade the quality of a tributary. More than one of the Columbia's tributaries suffer violations of legal water quality criteria, with nonpoint influences most often responsible.

DATA AND METHOD

The bulk of the data upon which this report is based was developed in a year-long comprehensive survey conducted cooperatively in 1972 by the Oregon Department of Environmental Quality, the Washington Department of Ecology, and EPA's Region X. Information on total dissolved gases was drawn principally from information collected since 1965 by the National Marine Fisheries Service. These sources were supplemented by thousands of pieces of information contained in STORET, EPA's computerized system of water quality data. Published reports were also used, including the *Proceedings of the Lower Columbia River Enforcement Conference*, *Water Pollution Control and Quality Management Programs of the Pacific Northwest*, *Water Pollution in the United States*, *Third Report of the Special Advisory Committee on Water Pollution*, *Columbia-North Pacific Region Comprehensive Framework Study of Water and Related Lands (Appendix XII: Water Quality and Pollution Control)*, *Pacific Northwest Drainage Basins*, and *Nitrogen Supersaturation in the Columbia and Snake Rivers*.

While these data are generally adequate to form a judgment as to the overall quality of the Columbia and the relative influence of various pollutants, they are of less breadth and specificity than might be desired for either scientific management of stream quality or anticipation of changes in quality. There are obvious gaps in the information (Table VIII-3). While collection of data for the Columbia may be of less immediate concern than for more threatened streams, the significance of the river to the ecology of the Pacific Northwest makes it imperative that those gaps be progressively closed.

TABLE VIII-3

COLUMBIA RIVER BASIN: MONITORING REQUIREMENTS

	Data uses				Data available
	Water quality trends	Waste load allocations	Modeling	Water quality standards	
Physical					
Receiving water		X	X		Yes
Reservoirs		X	X		Yes
Outfall information		X	X		Partial
Tributaries & diversions		X	X		Yes
Groundwater accretion		X	X		Yes
Meteorological		X	X		Partial
Water quantity					
Streamflow	X	X	X		Deficient in estuary
Stage, tide	X	X	X		Yes
Point-source discharge		X	X		Partial
Nonpoint-source discharge		X	X		No
Lake & reservoir water levels	X	X	X		Yes
Water quality					
Carbon	X	X	X	X	Partial, no trends
Nutrients	X	X	X	X	Partial, no trends
Metals	X	X	X	X	Partial, no trends
DO, temperature, pH, and conductivity	X	X	X	X	Yes
Pesticides	X	X	X	X	No
Transfer ratio		X	X	X	Yes

TABLE VIII-3 (Continued)

COLUMBIA RIVER BASIN: MONITORING REQUIREMENTS

	Data uses				Data available
	Water quality trends	Waste load allocations	Modeling	Water quality standards	
Biological					
Phytoplankton & zooplankton	X				Partial
Benthic macroinvertebrates	X				Partial
Microorganisms	X	X	X	X	Partial
Algal & bioassays	X	X			No
Sediments					
Chemical composition	X	X	X		No
Particle size	X				No
Pesticides	X				No
Transfer ratio		X	X		No

The analytical method used in this report consists of an analysis of water quality parameters significant to either the stream itself (dissolved gases, temperature) or to a general understanding of water quality (dissolved oxygen, conductivity, hydrogen ion concentration) using methods described in Chapter I. Trends were based on a comparison of aggregated values for the years 1970-72 with those for 1967-69.

Materials balance models were prepared to depict movements of total nitrogen and total phosphorus through the system. The discussion of nutrients relies in large part on the relationships developed by those models. In addition, extensive heat budget studies and mathematical modeling of temperature were conducted in and after the summer of 1969 to develop an understanding of the thermal characteristics of the river, particularly as they relate to reservoir conditions. Those models, too, were used as background for discussion.

WATER QUALITY CONDITIONS

Harmful Substances

No "toxic material" in the conventional legal sense of the term other than radioactivity has been detected in the Columbia River at concentrations approaching toxic levels. However, supersaturation of dissolved gases creates toxic conditions for spring-migrating strains of Columbia River salmon, and all resident fish species except bottom fish.

Gas Supersaturation. The toxicity of supersaturation is not limited to particular species or age groups, nor is it manifested only in reduction of life functions or spawning success. It is often lethal as lethal to the 50-pound adult Chinook Salmon migrating upstream to spawn as it is to the juvenile fish passing downstream to the sea. Other, less direct, manifestations of toxicity are also involved. Supersaturation increases susceptibility of fish to disease, other toxins, and temperature variation; by interfering with life processes, it makes fish less able to avoid predators.

The pathology of supersaturation is most intense in the upper layers of the water column. Because of hydrostatic pressure, the concentration of gas that constitutes saturation increases with depth. Equilibration takes place at the interface of air and water and is promoted by turbulence. But the great depth of the Columbia's reservoirs and the absence of surface turbulence in the pools inhibit the rate of gas exchange. With fairly stable concentrations through the water column, then, the degree of supersaturation is greater near the surface. Deep-swimming fish will not be harmed, but when forced upwards by barriers to migration or when passing through plumes of heated water (higher temperatures accelerate the gas exchange reaction), they develop gas bubbles in the bloodstream. Depending on the degree of supersaturation, the effects can be extreme. Severe impairment of function or death invariably follows. The eyeballs of an adult salmon can literally burst from the sockets under the pressure of an embolism.

While any amount of dissolved gas in excess of normal saturation levels may be toxic, probability of effective toxicity is thought to increase with degree of supersaturation. It is probable, too, that supersaturation is natural to many reaches of the Columbia under high flow conditions, given the great velocity of the river and the numerous falls and rapids in its natural bed. (Concentrations of 110 to 112 percent of saturation have been measured on the Salmon River, an unregulated stream whose characteristics were similar to the Columbia's before dams were built.) But man's actions have vastly increased both the area and the degree of hazard. Levels in excess of 140 percent of saturation have been recorded on the Columbia River in recent years (Figure VIII-3). During peak flows, the supersaturated condition is present over the whole length of the Columbia River in the United States.

Today, dams rather than falls or rapids are responsible for supersaturation. With 13 structures spaced over 900 miles of stream, the succession of artificial falls and slack water reinforces and maintains supersaturation, never allowing the stream to achieve a pressure equilibrium. The 24 dams located close to the Columbia on tributaries help to maintain the condition by carrying supersaturated inflows with them to the Columbia main stem. While dissolved gas concentrations hover above 100 percent of saturation through the river, peaks in excess of 120 percent are common below Grand Coulee, Chief Joseph, Rock Island, McNary, John Day, The Dalles, and Bonneville Dams.

Radioactivity. The threat of radioactivity, present in the Columbia since the latter stages of World War II, has declined in the last decade. During the 1950's, radioactivity levels below the AEC's Hanford Works were greater than for any other stream in the United States.

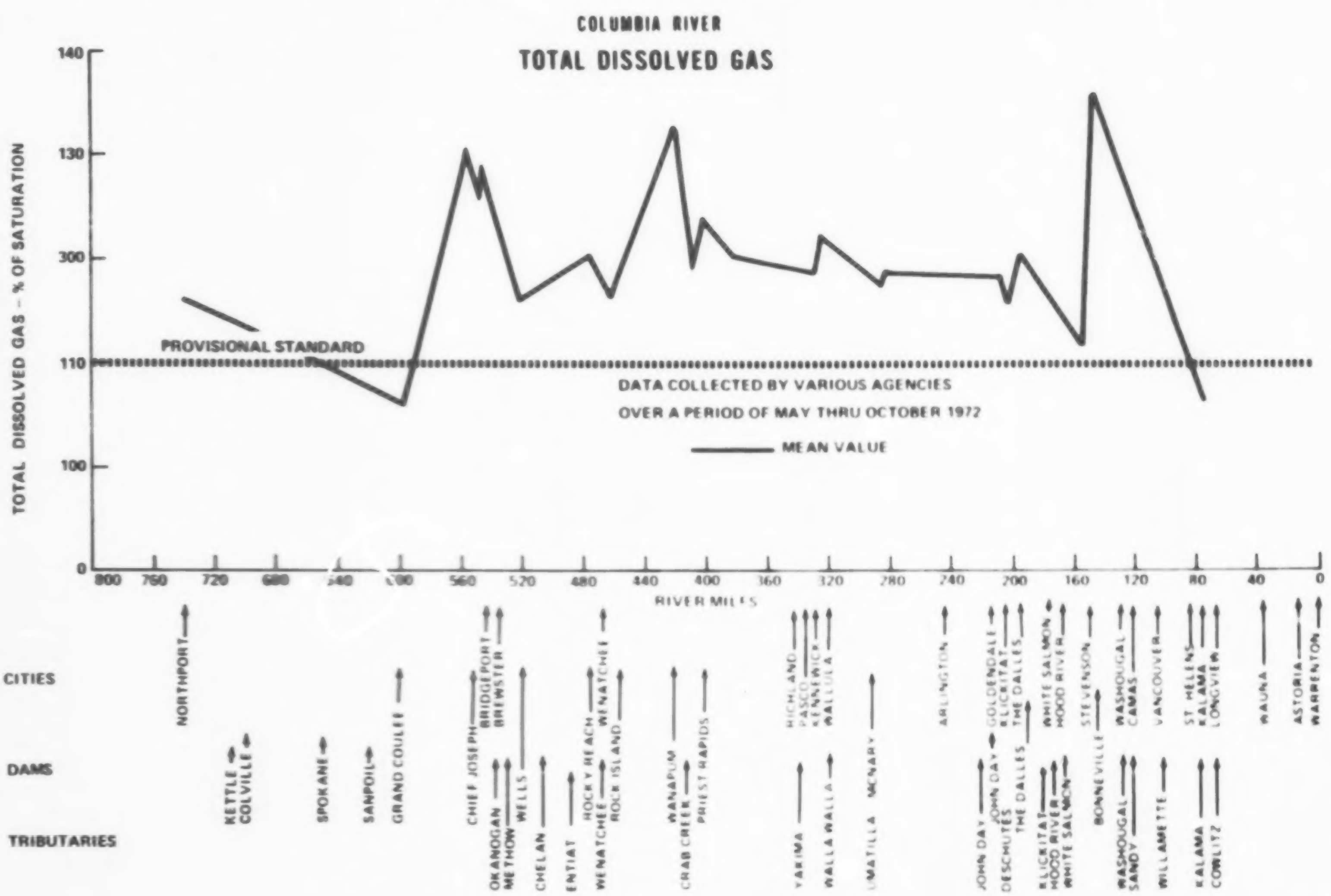
Public concern over radioactivity has moved Hanford to tighten its operations and waste containment procedures. More significant, perhaps, the bulk of reactor capacity has been idled. In addition, ambient radioactivity has dropped because of cessation of weapons testing in the atmosphere. Although there is still a significant rise in radioactivity below Hanford, the monitoring networks maintained by Battelle-Northwest and the AEC have detected no gross beta counts in excess of the recommended drinking water standard maximum of 1,000 pc/l since the winter of 1964. (Specific radionuclides that concentrate in the food chain, zinc-65 and phosphorus-32, continue to be detected at measurable levels to the mouth of the Columbia and in oysters taken on the Washington coast. Efforts to control and reduce the extent of their escape to the environment continue.) Beta counts have continued to drop since 1964 (Table VIII-4). In January 1971, the last production reactor using single-pass cooling with river water, the KE reactor, was shut down. This has resulted in a further substantial decrease in radionucledes such as zinc-65 and phosphorus-32 released to the Columbia River.

TABLE VIII-4

COLUMBIA RIVER RADIOACTIVITY

Location (river miles from mouth)	Average gross beta count 1964 (picocuries per liter)	1968	Reduction %
Northport (734)	10.8	5.0	53.7
Wenatchee (450)	11.9	5.0	58.0
Pasco–below Hanford (328)	710.0	140.5	80.2
McNary (289)	290.5	47.0	83.8
Bonneville (146)	250.2	47.0	81.2

Figure VIII-3 RIVER PROFILE



COLUMBIA RIVER

TOTAL DISSOLVED GAS

Public concern about radioactivity, however, has risen as counts have declined. Broadening awareness of the phenomenon, the advent of nuclear power plants, and the uncertainties associated with radioactivity—all probably contribute to public discomfort. At this time, fears seem to center about the location of nuclear-power plants and the possibility of accidents involving radioactive materials. The more than 100,000 gallons of low-level radioactive wastewater spilled by an AEC contractor at Hanford in the summer of 1973 reinforced such fears.

Physical Modification

Construction of dams and discharge of heated effluents are the two primary sources of man-made physical alterations of the Columbia.

Engineered Modifications. Dams and reservoirs are the most obvious alterations of the Columbia's physical conformation. The dams themselves are imposing, obvious structures. They have turned a turbulent, free-flowing river into a series of deep, swift pools. Other dams on tributaries have modified the flow pattern, reducing spring peaks and supplementing fall shortages.

Dams have caused physical modifications other than alteration of flow, and in the process they have changed the ecology of the Columbia. Settling of solids in reservoirs increases the clarity of the stream, but the consequent initial increase in light penetration contributes to growth of algae. Temperature stratification and temperature increases are also perceptible in the upper layers of reservoirs. Bacterial populations are probably reduced through natural die-off. Ponding results in more abundant, but less diverse, biological development. Grand Coulee Dam creates an impassable barrier for salmon, isolating the upper river.

The river is open to navigation from its mouth at the Pacific coast to Lewiston on the Snake River. Above Portland, commercial navigation is by barge, but to Portland, the channel is dredged to a depth of 40 feet. Each year, channel maintenance requires the removal of some 10 million cubic yards of sediment. Deep water harbor facilities are located at Vancouver, Longview, St. Helens, and Astoria; most river communities have barge handling facilities. Recreational moorages and launching ramps occur over the length of the river, and relatively slack water locations in the lower river are used for massive log storage. Diking, particularly in the Portland area, has altered the course and flow of the stream. The Columbia is bridged at a number of places, and highways and railroad tracks line both banks.

Two radical alterations of the physical features of the Columbia are under active consideration, both involving transportation. One proposal calls for dredging the main channel to 45 to 50 feet as far as Portland to accommodate the grain ships, tankers, and container vessels that will dominate traffic on the lower Columbia; in view of the evolution of vessel technology, 60-foot depths or more may become necessary to maintain the vitality of ports. There are also proposals to fill a substantial acreage of the Columbia at Portland airport—already built on filled river bed—to allow it to handle larger commercial jets.

Temperature. Less apparent but more significant than the structures that modify the physical characteristics of the Columbia is the long-term shift that man has induced in its temperature. Few water quality variables have a wider range of effects than temperature. Elevated temperature at the extreme can be lethal to fish, and even below the lethal level it is toxic to certain species of cold water fish in that it modifies migration behavior, reduces percentage of eggs that hatch, and favors the development of strains that are either predators upon cold water fish or compete with them for food. Diseases and parasites of fish rise in geometric relation to temperature. The temperature-disease relationship is a continuous, if fluctuating, source of pressure on Columbia River fish production. Extreme short-term temperature variation may be directly toxic. Virtually all chemical and biological reactions are accelerated as temperature rises. Thus, bacterial regrowth, exertion of BOD, metabolic processes that result in dissolved gas embolisms, and chlorination of organic solids—all are amplified as temperature increases and all are generally conceded to be undesirable.

The critical importance of temperature has been recognized by the States of Oregon and Washington; their water quality standards are devoted in great measure to preserving an environment capable of sustaining the valuable

Pacific salmon. While temperature criteria are complex and somewhat different for the two States they essentially prohibit discharges that will result in a measureable increase when river temperatures are 20°C or higher. (Somewhat different boundary levels are set for varying stream reaches. However, the level that applies over the stretch of river in which temperature is a concern is 20°C.)

The major influence on water temperature is the temperature of the surrounding atmosphere, making late summer the critical season. The Columbia's temperature profile for June through September reveals a progressive increase as the river passes to lower, warmer elevations (Figure VIII-4). The pattern holds from the international boundary to a point below Longview, Wash. The increase is most marked below Bonneville Dam; at Longview-Rainier, median water temperatures regularly reach or exceed the 20°C limit. In summer, 15 percent of readings exceed 20°C from McNary pool downstream.

Whether high temperatures in the lower river represent a violation of the legal criteria is uncertain because of the way that the water quality standard is expressed. Pooling behind dams, tidal blocking below Bonneville Dam, and the influences of the relatively warm Cowlitz, Willamette, Snake, and Yakima Rivers contribute to rising temperatures, but since they do not result from discharges, they are not considered standards violations. How much the heated discharges of the Portland metropolitan area and the forest products complex at Longview add to the temperature of the Columbia is a difficult question, but their effect may be slight.

The critical point in the system is the reservoir behind McNary Dam, where the Columbia becomes a broad, extensive pool. Already warmed behind Grand Coulee and Rock Island Dams, the river receives the warmer waters of the Snake and Yakima Rivers. On a bare, high plateau it absorbs enormous quantities of solar energy from typically cloudless skies. And into that pool, the various works at Hanford discharge 2 billion gallons a day of heated water. Downstream from Hanford, summer water temperature customarily exceeds 21°C, and temperature rises of 1.1° to 2.8°C have been documented in the vicinity.

Below McNary Dam the environment of the Columbia offers little opportunity for the temperature to decrease. A series of pools are formed behind John Day, The Dalles, and Bonneville Dams. Persistence of clear skies and high temperatures to the edge of the Cascade Mountains keeps water temperature high through the Columbia Plateau. Even at Portland, costal influences are not enough to reduce temperatures, and the tidal flux acts to hold back heated waters as far as Bonneville Dam for 12 hours of each summer day.

At the present time, then, the Columbia touches or exceeds the established upper temperature limit in August, and under unfavorable atmospheric or flow conditions, even in July and September. The pattern would seem to be set by natural conditions and the flow regimen, but modification of flow by damming has certainly altered the pattern. Analysis of temperature records and mathematical modeling indicate that peak temperatures now occur up to 60 days later than they did on the unregulated river. No change in temperature levels appears to have occurred from 1967-69 to 1970-72: Median temperatures at five monitoring stations indicate that the very slightly cooler waters in the critical season for the period 1970-72 as against 1967-69 can be explained entirely by variation in flow and relative influence of the various tributaries. Figure VIII-5 shows monthly temperatures for three monitoring stations. No dramatic shifts can be anticipated in a situation so largely governed by natural conditions. Yet the possibility persists that the temperature profile may shift upward in the future if heated discharges increase. That possibility, inherent in industrial growth of all types, will most likely occur as the Northwest converts from hydroelectric to nuclear power plants discharging massive volumes of cooling water (Table VIII-5).

Eutrophication Potential

Little evidence exists to indicate current or potential eutrophication problems on the Columbia. Biological productivity and the availability of nitrogen and phosphorus nutrients were examined in order to assess any problems of the river.

Productivity. The Columbia is an immensely productive stream. For thousands of years it has supported a variety of life forms in great abundance. With the exception of the *Sphaerotilus* growths of the lower river, all indications

Figure VIII-4 RIVER PROFILE

COLUMBIA RIVER

WATER TEMPERATURE

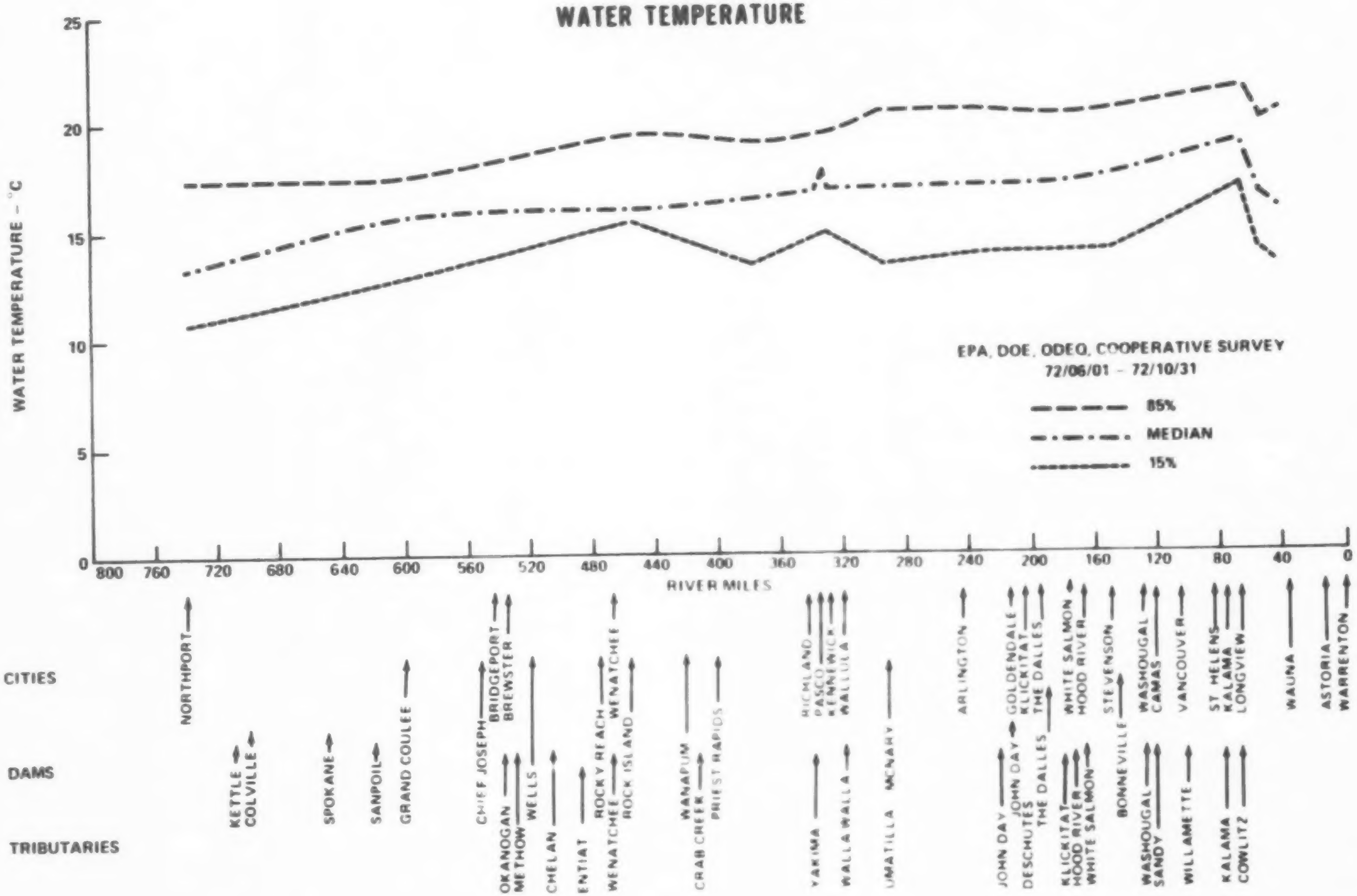


Figure VIII-5 TIME TRENDS AT RIVER MILEPOINTS
COLUMBIA RIVER
TEMPERATURE

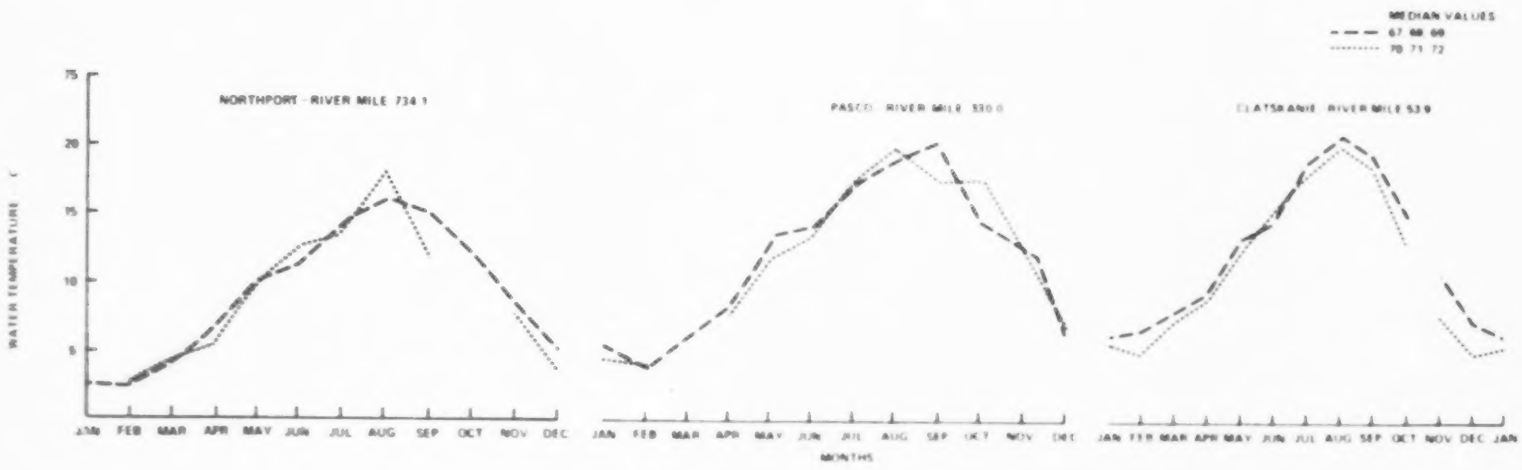


TABLE VIII-5

COLUMBIA RIVER THERMAL POWER PLANTS

Location	Capacity (megawatts)	On line
Hanford, Wash. (No. 1)	860	Existing
Rainier, Oreg.	1,130	1974
Hanford (No. 2)	1,100	1977
Boardman, Oreg.	1,200	1980
Hanford (No. 1 expansion)	350	1980

are that the productivity has been diverse and balanced, the antithesis of eutrophic conditions. (The *Sphaerotilus* episode is attributed to excessive wood sugars or fibers from pulp and paper mills, and not to a general excess of nutrients.)

There are differences in the apparent productivity of the reaches of the river. Above McNary pool, the characteristic summer color of the Columbia is a brilliant green, indicating a probable excess of light-reflecting algae; in and below the pool, color shifts to blue or gray, reflecting the covering sky and indicating a relative reduction in biomass. Even in the upper reaches, the only manifestations of algae production are the color of the water and a very moderate diurnal variation—less than 2 percent—in dissolved oxygen saturation due to the respiratory cycle of aquatic plants. There have been no reports of nuisance algae or of the usual symptoms of excess productivity—visible slime growths, noticeable variations in dissolved oxygen saturation values, and oxygen depletion. The apparent reduction in algae concentrations in the lower reaches is probably due to the settling of algae in reservoir pools, where their decomposition results in either the incorporation of nutrient phosphorus in bottom muds or its gradual recycling through the water column into new organisms. By regulating the presence and production of algae in that fashion, the lower dams probably serve to improve the quality of the river. Conversely, storage behind Grand Coulee Dam may act as an incubator for algae development.

Nutrients. Adequate amounts of all nutrients necessary for a diverse, abundant aquatic ecology are present in the Columbia. Nitrates are present during most of the year in concentrations significantly in excess of the 0.3 mg/l limit that is somewhat arbitrarily associated with nuisance algae blooms. In fall and winter, median concentrations range from greater than 0.3 to greater than 0.4 mg/l from McNary Dam (RM 330) to the mouth; in spring, the median exceeds 0.3 mg/l from Longview (RM 68) to the mouth. Concentrations at McNary Dam exceed 0.8 mg/l in 15 percent of the readings (Figure VIII-6). The significance of these values is probably slight, both because atmospheric nitrogen is available and because other requirements for algae production—notably sunlight and water temperature—are substantially reduced in those seasons.

During the critical summer months, when other natural conditions are favorable for algae proliferation, median (and even 85th percentile) nitrate concentrations fall well below the 0.3 mg/l threshold. However, what is measured is nitrogen in excess of production requirements. Thus the decrease may well be due to uptake by growing organisms.

Phosphorus concentrations are probably a more meaningful regulator of aquatic growth than any other variable. For analytical purposes, it is often assumed that concentrations of total phosphorus in excess of 0.05 mg/l and of dissolved phosphorus in excess of 0.01 mg/l will result in nuisance blooms of algae in the absence of inhibiting factors.

Median total phosphorus concentrations in the Columbia exceed the hypothetical 0.05 limit from McNary Dam to the mouth in winter and fall; in spring the level is exceeded over the full reach of the river in the United States (Figure VIII-7). During the warmer months, however, the median is consistently below the hypothetical limit,

Figure VIII-6 RIVER PROFILE

COLUMBIA RIVER

TOTAL NITRATE

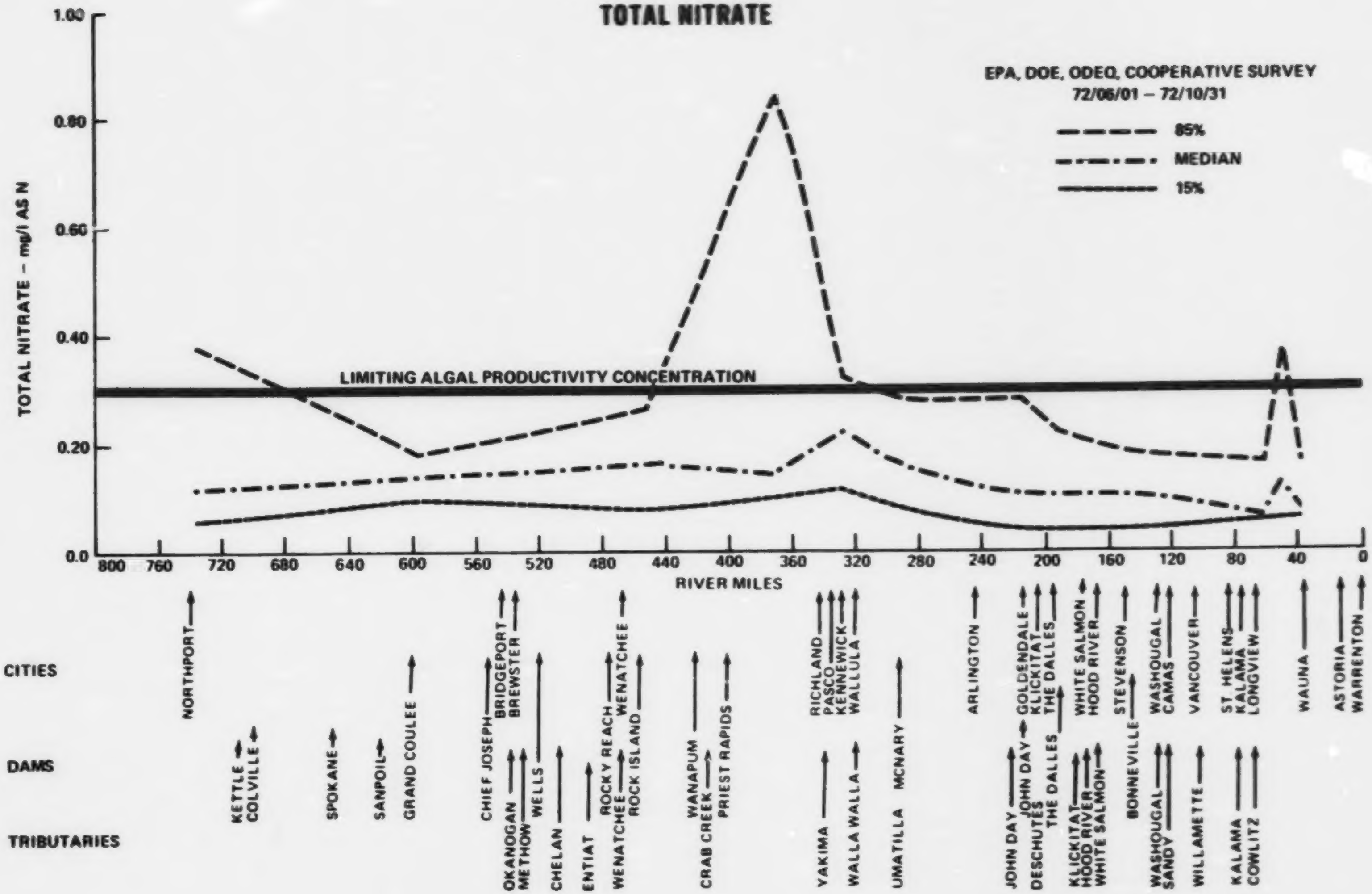
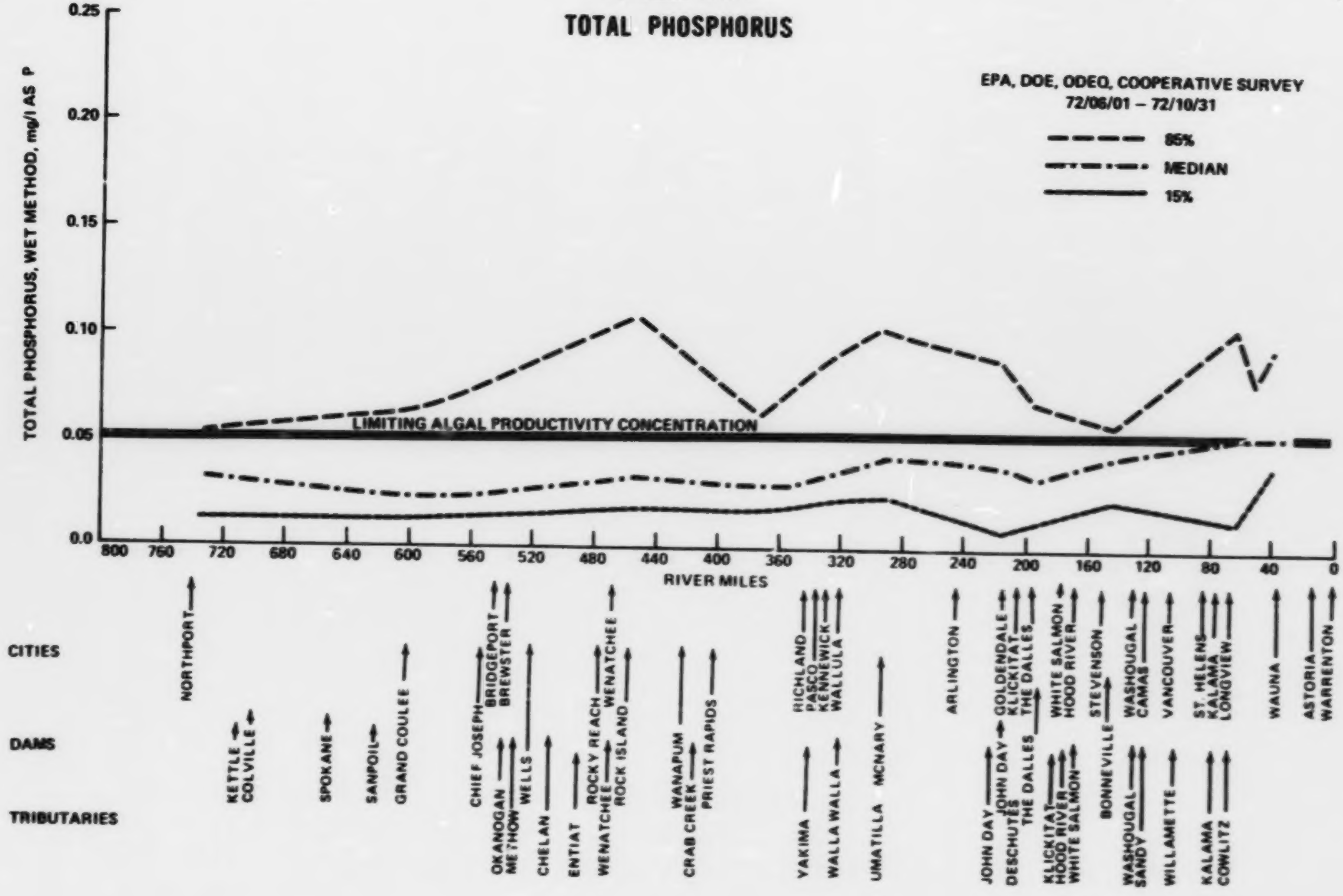


Figure VIII-7 RIVER PROFILE

COLUMBIA RIVER

TOTAL PHOSPHORUS



except in the lower 60 miles. Total phosphorus concentrations appear very sensitive to flow. Thus a plot of median monthly concentrations against flow, recorded at the time the median sample was taken at any of the five routinely monitored water quality stations, indicates that phosphorus contributions are greater in high-flow years than in low-flow years, and that high-flow periods in any year exhibit higher total phosphorus concentrations than low-flow periods (Figure VIII-8).

Phosphorus concentrations were higher in 1970-72 than 1967-69, probably because of generally higher flows in 1970-72. Unlike the cases of temperature and dissolved gas, there is no indication that the effects of human activities are causing any significant increase or decrease, except to the extent (necessarily minor, given relative quantities of waterborne and agriculturally applied phosphorus) that phosphate fertilizers may be a source of nutrient phosphorus.

The data suggest that total phosphate concentrations are largely a function of runoff. The general flow-to-concentration correlation, as well as the fact that highest concentrations are uniformly recorded with the first flush of the spring flood, indicates that total phosphorus is principally derived from soil-bound phosphorus and is runoff dependent.

This conclusion is reinforced by considering the relative size of total phosphorus sources. In 1972, 6 percent of the annual loading of the Columbia occurred from point sources (mostly municipal sewage treatment plants) discharging directly to the Columbia, 65 percent was carried to the Columbia by its major tributaries, and 29 percent was accounted for by other mechanisms–among them minor tributaries, direct runoff, recirculation, and sedimentation. The significance of runoff is again supported by the analysis of sources, for the distribution of loadings from various tributaries correlates closely with their patterns of flow (Table VIII-6).

In the case of dissolved phosphorus (the portion directly available as a plant nutrient), the relationship of observed concentrations to hypothetical limits for excess aquatic growths is somewhat different. Except in the critical season, median concentrations exceed the hypothetical 0.01 mg/l limit for nuisance growths over the entire length of the River. But in summer, the median is uniformly beneath the hypothetical limit downstream of Rock Island Dam (Figure VIII-9). The areas of high dissolved phosphorus are well above any significant discharge points; the concentration of point sources at and below Portland does not demonstrably increase the range of concentrations.

The general pattern that emerges, then, suggests that the Columbia River is adequately supplied with nutrient phosphorus and nitrogen throughout the year, that natural sources rather than waste discharges supply the bulk of those nutrients, and that the seasonal cycle of their supply makes circumstances other than nutrient availability responsible for controlling the rate of production of aquatic flora. No trends can be observed that suggest an alteration of a pattern of diverse, prolific, and balanced production of biota.

Salinity, Acidity, and Alkalinity

Neither salinity nor acidity poses even a hint of a problem on the Columbia. In terms of the broad chemical indicators–mineralization measured as conductivity, and hydrogen ion concentrations (pH)–the Columbia approaches the ideal for fresh waters.

The stream runs from moderately alkaline (pH 7.9 to 8.1) in its upper reaches to neutral as it approaches the mouth. There is slight seasonal variation. In the first quarter, flows in the lower river are dominated by tributaries arising in and west of the Cascades, an area thickly forested, humid, and characterized by organic, slightly acid soils. In consequence, its runoff is significantly less alkaline than that of upriver areas; during heavy winter rains, the reach of the Columbia below the mouth of the Willamette tends to be very nearly neutral (Figure VIII-10).

Mineralization is slight and decreases downstream (Figure VIII-11). Conductivity is highest in late fall, when flows are low; in the upper river, conductivity is influenced by irrigation returns. In general, median conductivity

Figure VIII-8 TIME TRENDS AT RIVER MILEPOINTS

COLUMBIA RIVER

TOTAL PHOSPHOROUS AND FLOW

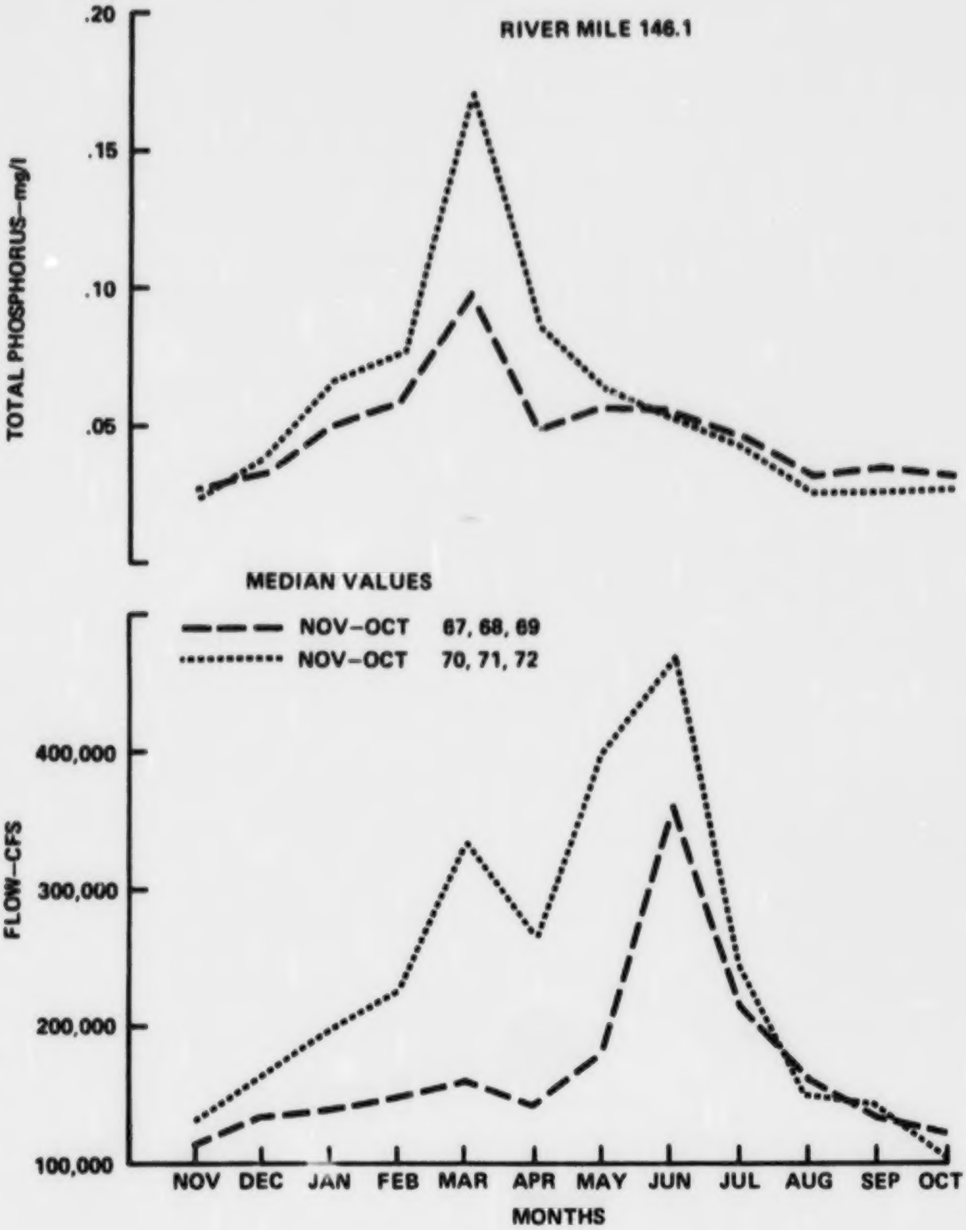


TABLE VIII-6

COLUMBIA RIVER: PHOSPHORUS CONTRIBUTIONS (1972)

Source	Phosphorus (lb./day)			
	1st Quarter	2d Quarter	3d Quarter	4th Quarter
Point sources to mainstream	7,508	7,508	7,508	7,508
Tributaries:				
Kettle River	40	120	2,314	66
Colville River	85	240	125	35
Spokane River	2,130	13,639	4,404	928
Sanpoil River	10	456	134	6
Okanogan River	160	840	12,157	188
Methow River	17	153	3,691	55
Chelan River	189	62	191	144
Entrat River	15	83	468	195
Wenatchee River	122	1,109	801	220
Crab Creek	186	251	230	161
Yakima River	1,934	12,446	7,188	1,534
Snake River	19,953	68,745	34,615	4,643
Umatilla River	796	20,501	289	29
John Day River	3,810	45,071	–	54
Deschutes River	3,506	4,411	2,065	2,127
Klickitat River	859	2,133	426	381
Hood River	575	658	–	141
White Salmon River	416	420	310	237
Washougal River	228	453	38	72
Sandy River	1,363	2,108	237	72
Willamette River	83,444	50,453	6,354	4,967
Lewis River	781	25,030	606	212
Kalama River	458	7,802	75	57
Total	128,585	264,692	84,226	24,032
Columbia at RM 38.9	190,742	199,366	203,049	42,146
Balance (Background + direct runoff + sedimentation + recirculation)	62,157	-65,326	118,823	18,144

measurements correspond roughly to a concentration of total dissolved solids under 150 mg/l. (The recommended drinking water standard is 500 mg/l or less.)

Oxygen Depletion

Dissolved oxygen concentrations provide one of the most universal indicators of the quality of a waterbody. Oregon's water quality standards require that the Columbia River's dissolved oxygen concentration be equal to or greater than 90 to 95 percent of saturation, depending on time of year. The Washington criterion requires at least 8 mg/l of dissolved oxygen. Neither criterion is often breached. (Because saturation is both pressure- and temperature-dependent, the discussion and graphs that follow are keyed to the constant Washington standard of 8 mg/l, rather than the situation-influenced Oregon standard.)

Median dissolved oxygen concentrations exceed 10 mg/l in the upper river in summer, rise to above 12 mg/l below Grand Coulee Dam, recede to the 10 mg/l level in McNary pool, and repeat the cycle at each downstream dam. There is a pronounced depression in the stream reach from Portland to Longview, where some 600,000 pounds of BOD are discharged directly each day, and where another 100,000 pounds or more enter with waters of the

Figure VIII-9 RIVER PROFILE

COLUMBIA RIVER

DISSOLVED ORTHOPHOSPHATE

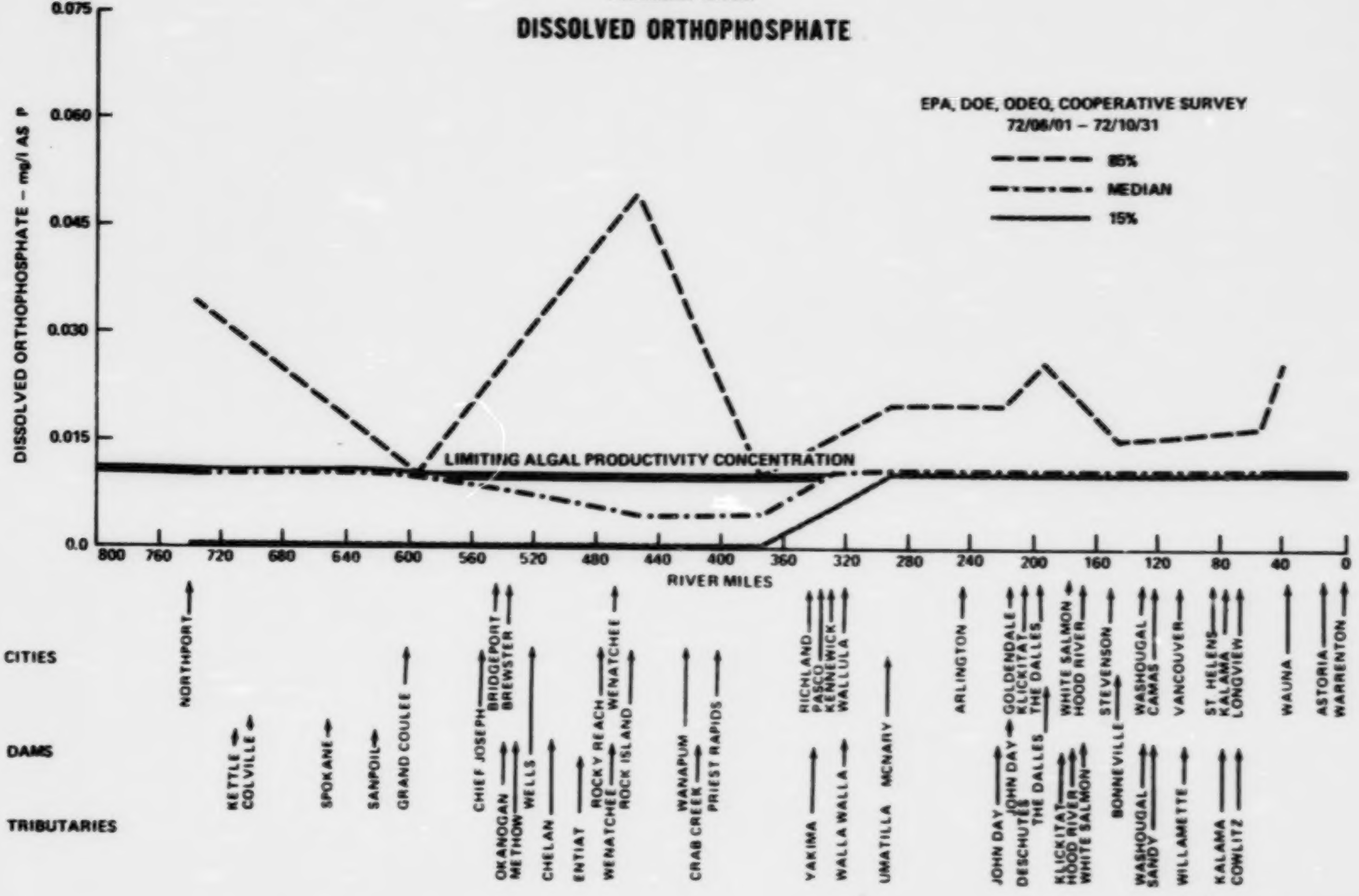


Figure VIII-10 RIVER PROFILE

COLUMBIA RIVER

pH

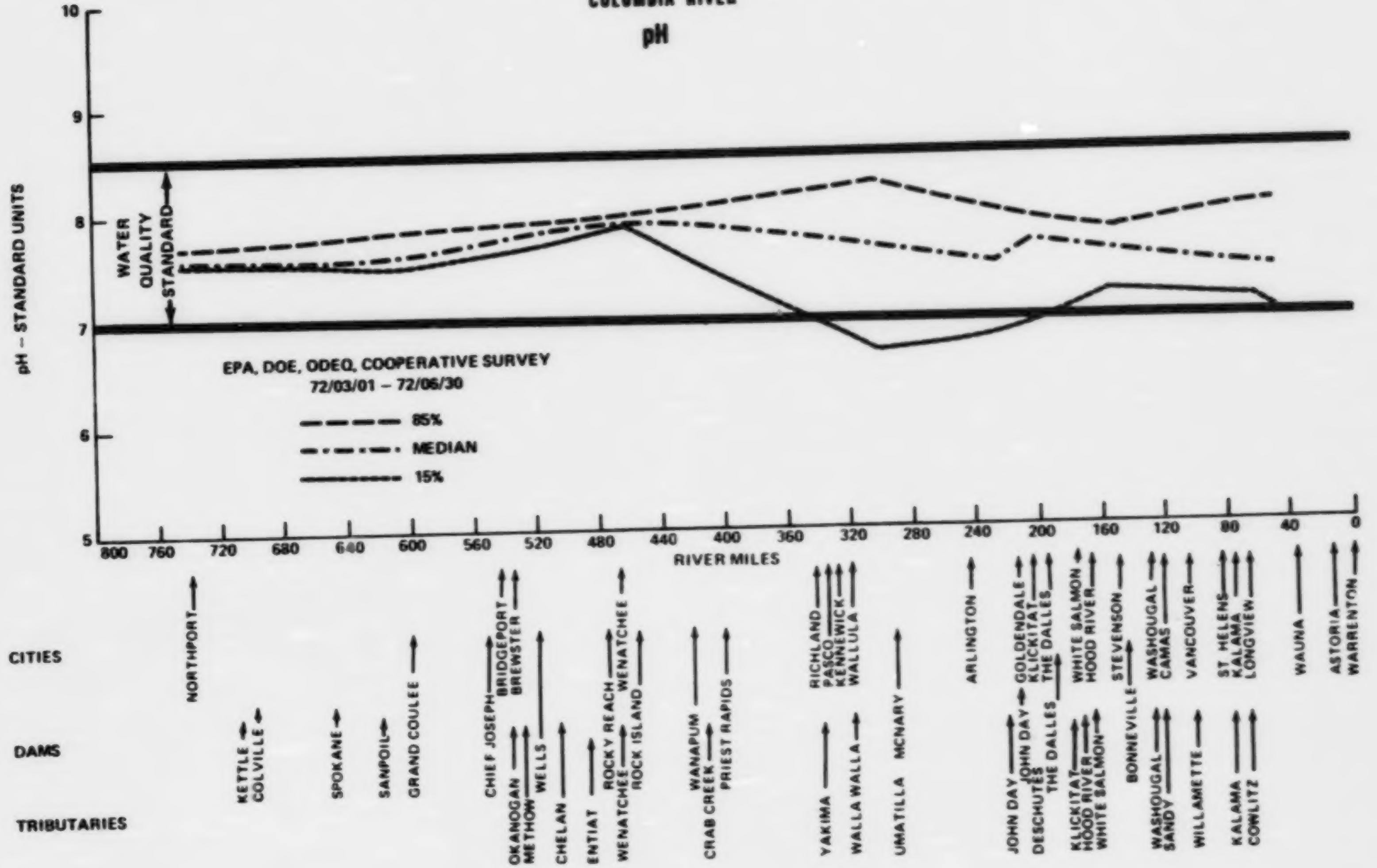
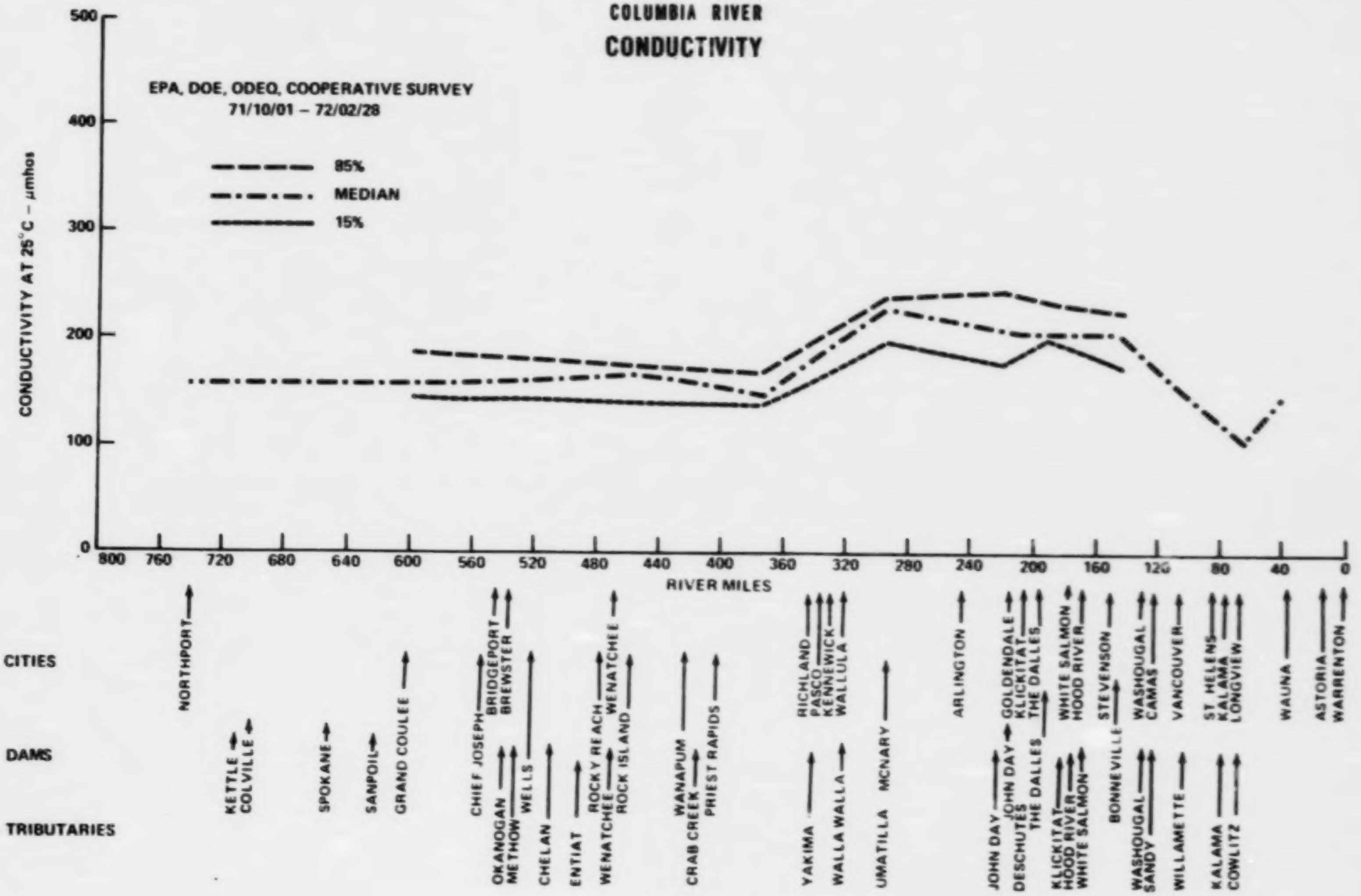


Figure VIII-11 RIVER PROFILE



COLUMBIA RIVER

CONDUCTIVITY

EPA, DOE, ODEQ, COOPERATIVE SURVEY
71/10/01 – 72/02/28

Willamette. It would be rash, however, to conclude that the depression is due entirely to exertion of this BOD. More fundamental factors are operative. The entering Willamette—roughly one-eighth the volume of the Columbia—has a dissolved oxygen concentration that in summer is typically 3 to 5 mg/l lower than that of the receiving stream. Tidal blocking extends upstream to Bonneville Dam, and the reach below Bonneville has the maximum temperature on the river (Figure VIII-12).

There is a definite seasonal rhythm to dissolved oxygen concentration in the Columbia. Peaks occur in late winter and early spring, and troughs in late summer and early fall (Figure VIII-13). Although flow may play some role in the variation, temperature is probably the more significant variable. Supersaturation, algal respiration, relative inflow, and dissolved oxygen concentration of tributaries may all influence the seasonal pattern.

Dissolved oxygen concentrations in the Columbia River do not appear to be changing with time. Absolute readings in 1970-72 were slightly—and in a couple of cases, significantly—higher than in 1967-69. But when corrected for changes in temperature, the differences disappear. BOD from pulp mill discharges has been significantly reduced, but the effects are limited to the lower river. In view of the enormous assimilative capacity of that part of the river, their influence must be conceded to be slight.

In short, the natural assets of its tremendous volume, velocity, and surface area seem to be sufficient to provide the Columbia River at all times with dissolved oxygen concentrations that are very close to theoretical saturation. Any damage that man has done to the river has not offset its great natural advantages.

Health Hazards and Aesthetic Degradation

Bacterial counts on the Columbia today are significantly lower than they were 30 to 40 years ago. Columbia River water quality standards set a general limit of from 250 to 1,000 coliform-type organisms per 100 ml, depending on location, recurrence, and source. In general, median counts run closer to 100 than to 1,000—even in summer when higher temperatures are more favorable to life processes. The series of reservoirs on the Columbia unquestionably reduce bacteria counts by facilitating die-off and sedimentation.

Below Bonneville, the last of the reservoirs on the Columbia, bacterial counts rise steeply, frequently exceeding 1,000 per 100 ml (Figure VIII-14). This phenomenon led the lower Columbia to be designated "severely polluted" in the 1930's. The bacterial counts then were even higher and resulted from sewage discharges of the Portland area. Today, in view of modern understanding of bacterial population dynamics, the rise in bacterial concentrations must be considered more of a question, rather than certain evidence, of pollution. Total coliform counts rise and fall with precipitation, and particularly with runoff of the Willamette and other lower basin tributaries. Regrowth is fostered by an enriched environment. Whether the higher counts are indicative of pathogenic—or even fecal—organisms remains to be determined.

Unfortunately, reliable fecal coliform determinations are not available for the lower river, where total coliform counts are highest. Fecal coliform determinations made for the reach of river in and above McNary pool indicate that in that area, where median total coliform counts run between 200 and 500 organisms per 100 ml, fecal counts range between 10 and 30 organisms per 100 ml (Figure VIII-15).

Coliform counts of the lower river vary only slightly with seasons (Figure VIII-16). A pattern of late winter and late summer peaks—probably functions of runoff and temperature, respectively—can be discerned. A short-term trend to slightly higher counts in the last 3 years than in the preceding 3 should probably be dismissed as a consequence of difference in flow. There is good reason to believe that bacterial populations today are significantly less than those of 30 to 40 years ago, when high bacterial counts were a definite source of concern. It is difficult to say what brought about the reduction in the face of a large expansion of human population, significant urbanization with paving and other features facilitating runoff, and increase in waste sources. Certainly increased prevalence of waste treatment and of disinfection has played a part, but die-off in upriver reservoirs and flow regulation on tributaries are probably also involved.

Figure VIII-12 RIVER PROFILE

COLUMBIA RIVER

DISSOLVED OXYGEN

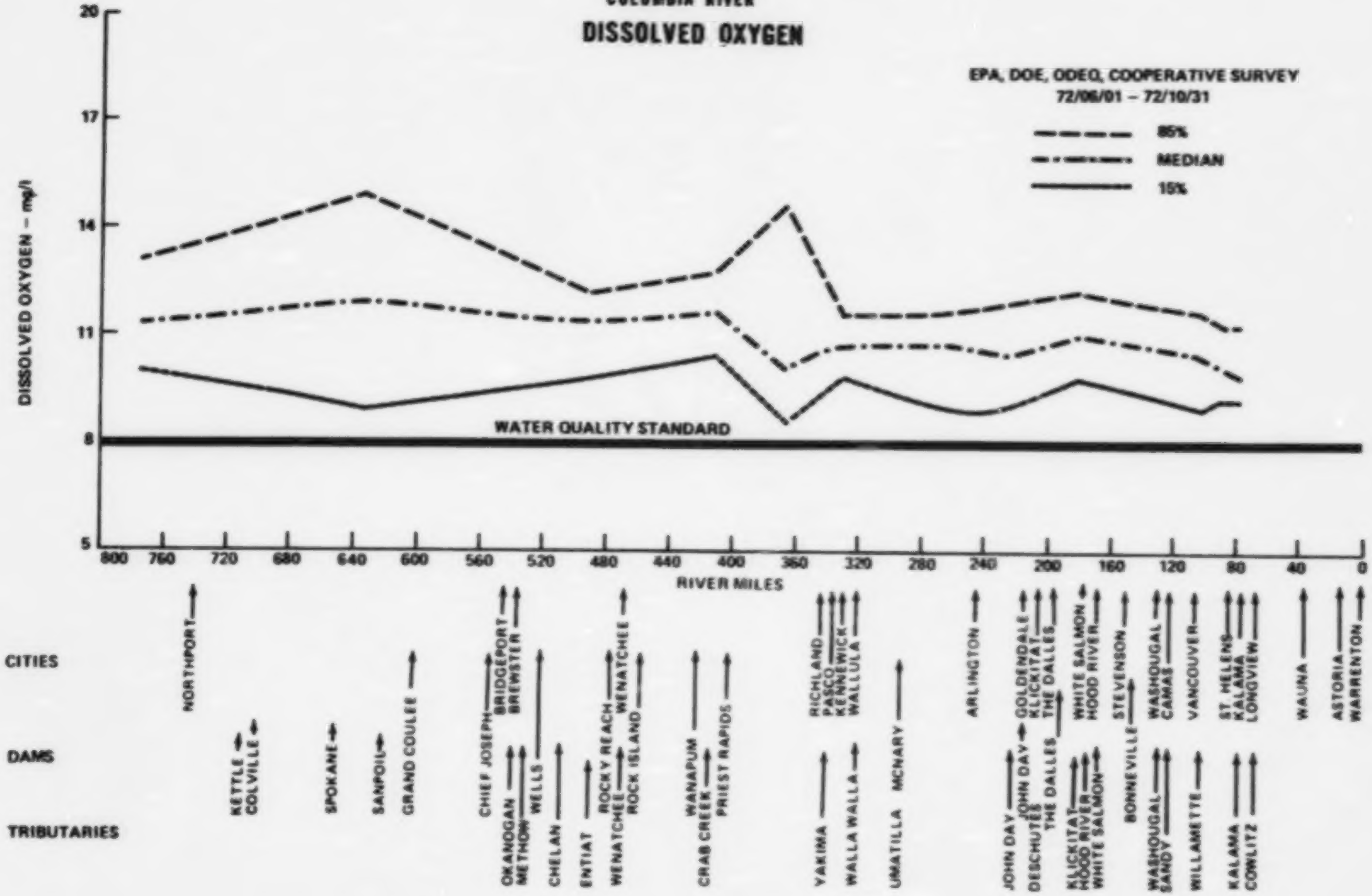


Figure VIII-13 TIME TRENDS AT RIVER MILEPOINTS

COLUMBIA RIVER

DISSOLVED OXYGEN

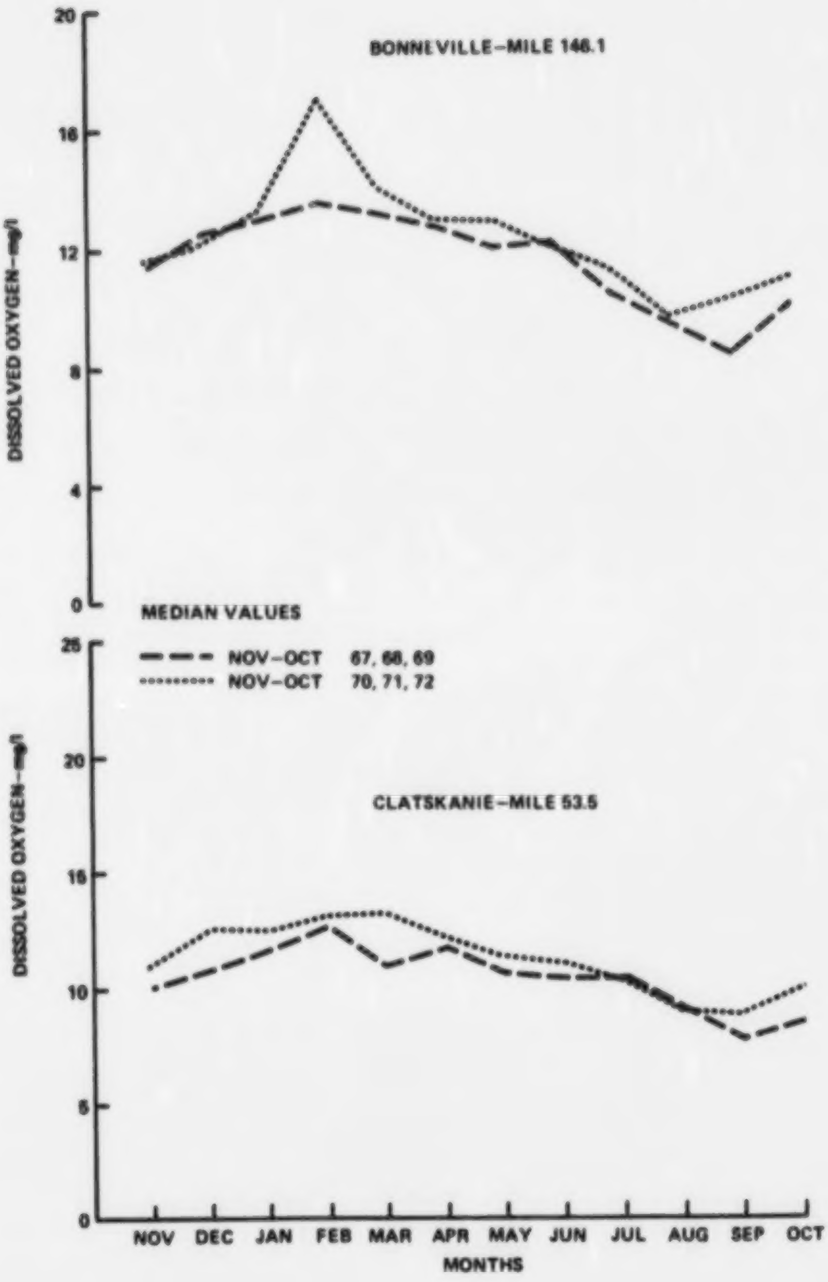


Figure VIII-14 RIVER PROFILE

COLUMBIA RIVER

TOTAL COLIFORMS

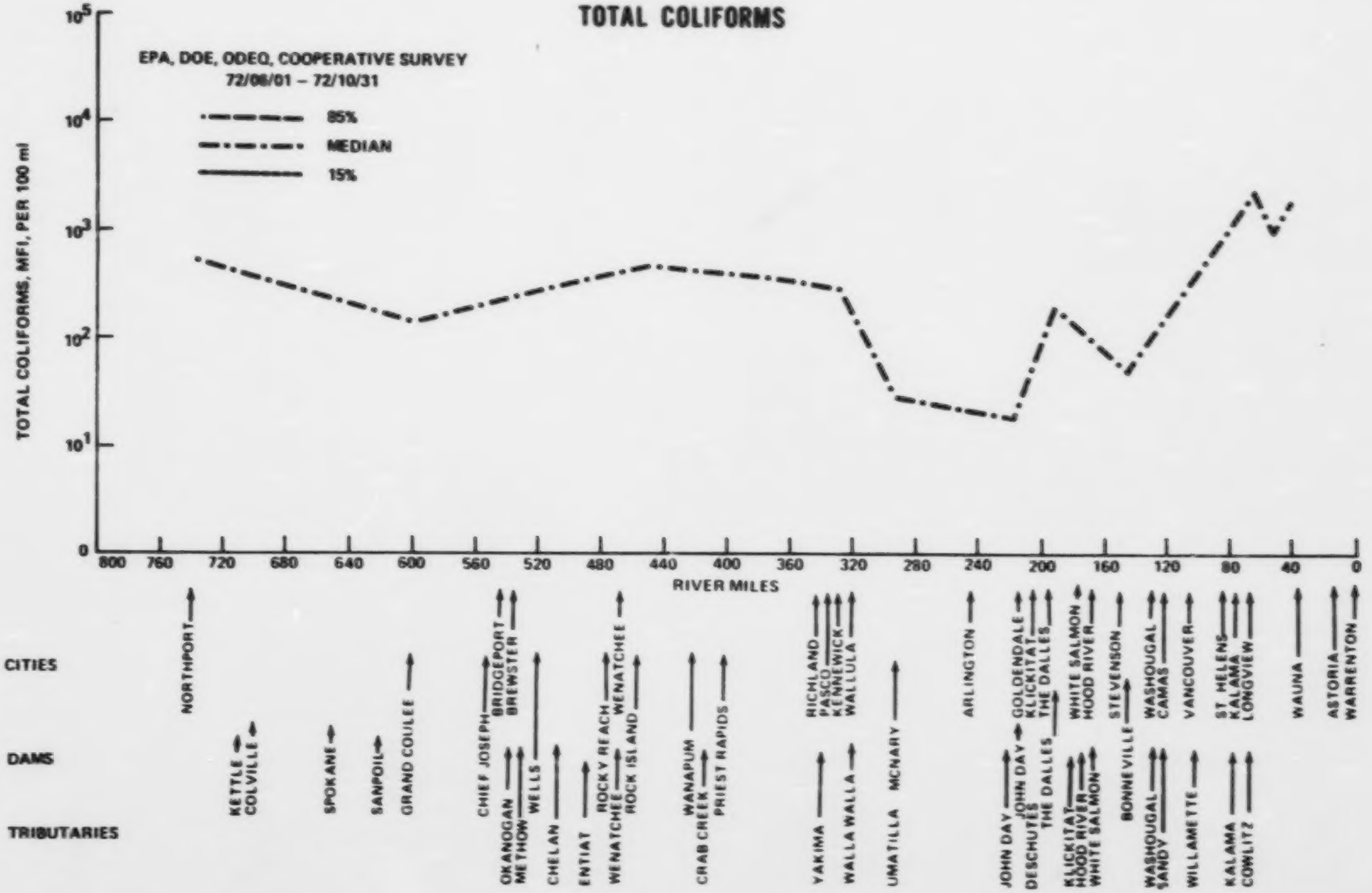


Figure VIII-15 **RIVER PROFILES**

COLUMBIA RIVER

FECAL COLIFORMS

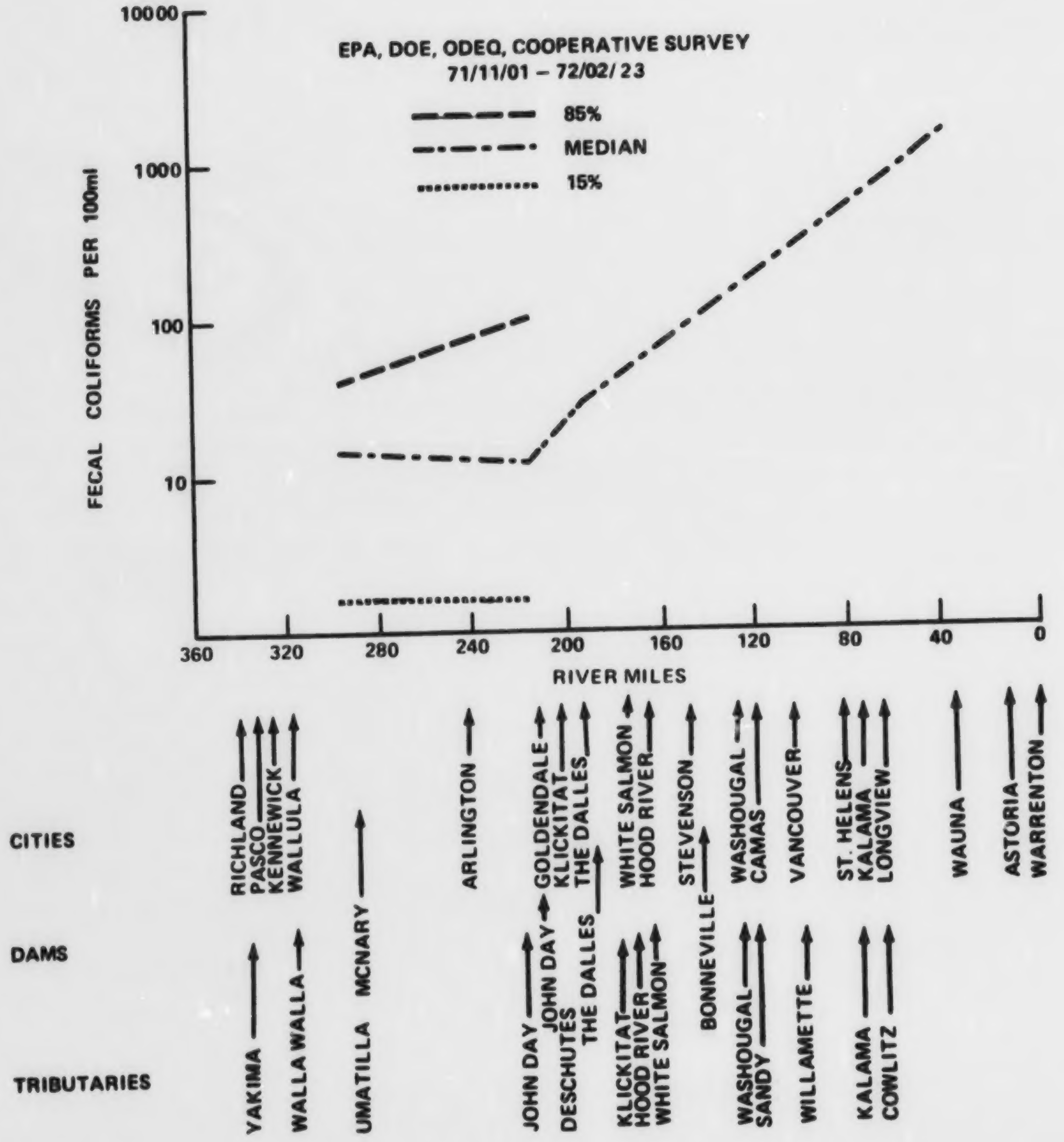
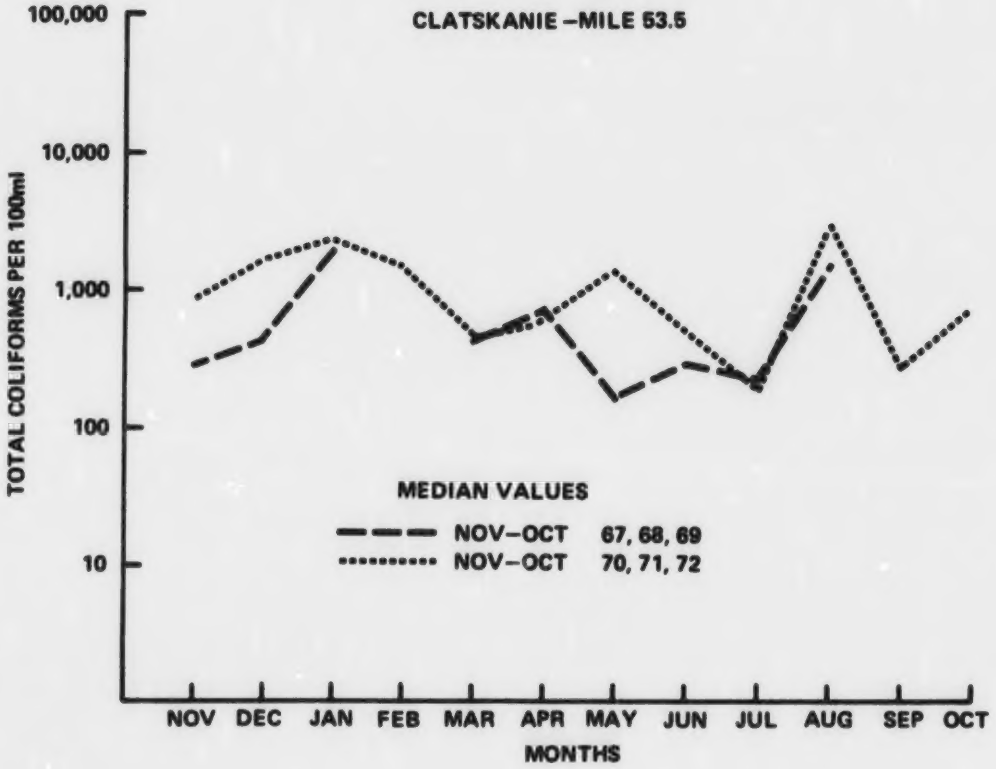


Figure VIII-16 TIME TRENDS AT RIVER MILEPOINTS

COLUMBIA RIVER

TOTAL COLIFORMS



PROJECTION

The generally high quality of the Columbia River deviates only slightly and intermittently from a pattern of compliance with its water quality standards. Criteria have recently been established for the major pollution problem, dissolved gas supersaturation.

Waste treatment is well advanced, and projects either under construction or being formulated will bring the significant dischargers, if not all dischargers, into compliance with effluent standards by the target date of July 1, 1977. Given the resource and time constraints, such progress represents a monumental accomplishment.

And yet two problems not fully addressed by Federal laws–gas supersaturation and temperature elevations related to dams and reservoirs–imply that the Columbia will probably not meet the goal of the 1972 Act of "water quality which provides for the protection and propagation of fish . . . by July 1, 1983." Dissolved gas supersaturation is a clear cut, thoroughly documented form of pollution that exists today, but since it does not arise from discharges, it is not directly controlled by Federal law. Biological and temperature studies have demonstrated a high probability that elevated temperature–due in some measure to the impact of human activity–is a source of existing pollution through its interference with fish populations. Temperature regulation involves a mixture of reservoir thermodynamics, which are not fully understood or addressed by Federal law, and case-by-case regulation of heated discharges (section 316 of the 1972 Act) with so many ambiguities that uniform controls may prove difficult to achieve.

Remedies are available, although they may have to be found in the areas of negotiation and State action, rather than existing Federal law. Fundamental changes in stream regulation–probably requiring both additional storage and additional hydroelectric generating capacity–are essential to alleviation of pollution by dissolved gases; such changes run directly counter to the evolving mode of power production, which will relegate hydroelectric capacity to use for peaking purposes as thermal generating capacity comes on line.

In short, in spite of its present high quality and higher than normal rate of progress toward compliance with the 1972 Act, the prognosis for the Columbia is uncertain at this time. The principal source of optimism is the fact that Pacific Northwest States have a history of leadership and cooperation in water quality management. In concepts and accomplishments, they have consistently outpaced the rest of the Nation. Should the trend be sustained, solutions to the complex problems will be developed regionally.

RECOMMENDATIONS FOR MONITORING

EPA's Region X has developed a monitoring strategy to support water quality management in the Columbia's drainage basin. The strategy consists of intense stream sampling surveys to determine the status of water quality; mathematical models to predict the effects of waste discharges, flow, temperature, and other variables; and routine monitoring at selected points to verify model predictions and detect shifts in system dynamics. The strategy will be correlated with the monitoring programs of the various States, both to optimize data collection procedures and to provide links between State and Federal regulatory and planning efforts. River basin water quality manuals will be produced and continually updated to interpret and summarize the great volume of data contained in the STORET and National permit systems.

Because the intensive water quality surveys that are the keystone of the strategy are expensive, it has been necessary to establish priorities to implement the system in the various Pacific Northwest watersheds. Priorities were determined by ranking the watersheds according to existing water quality. The Columbia, virtually free of pollution, ranks near the bottom of the list. Data deficiencies that must be eliminated in order to accomplish the procedure have been determined (Table VIII-3), and some of the needs will be routinely filled through implementation of permit and monitoring programs. Other data collection and model development will be deferred in keeping with established priorities until 1975, unless reevaluation of relative pollution raises the Columbia's position in the ranking of polluted streams.

IX. SNAKE RIVER

The Snake River has experienced frequent instances of pollution: nuisance algae blooms in the upper river and dissolved oxygen deficiencies at widely separated points, especially in reservoirs. Like the Columbia River, the lower river has severe dissolved gas supersaturation problems below hydropower dams. Turbidity is objectionable in the upper and middle river sections, and dissolved solids from irrigation return flows, erosion, and natural runoff are high in the middle section. Agricultural activity has introduced pesticides in the upper river. Bacteria from municipal and industrial discharges, as well as from runoff, cause most of the river to exceed legal criteria.

The key pollutants indicate current conditions in the Snake:

- *Harmful Substances.* Water flowing over hydropower dams causes severe dissolved gas supersaturation in the lower 285 miles of the Snake River. Pesticide concentrations have constituted a continuing source of potential toxicity in the waters of the agriculture-dominated upper and middle portions of the Snake basin; several fish kills have been documented in the second half of the 1960's.

- *Physical Modification.* Suspended sediments and other materials result in turbidity at times in the upper and middle portions of the river. The turbidity comes from natural erosion, agricultural practices, and reservoir flushing.

- *Eutrophication Potential.* The Snake River is excessively productive, with nuisance level algae blooms occurring each summer over much of the river. The noticeable growths are in reservoirs in the 540-mile river segment between Idaho Falls and Brownlee Reservoir. Nitrogen and phosphorus concentrations exceed theoretical algae-limiting concentrations throughout most of the river, but there is no evidence of significant increases in the past 10 years. Rich phosphate deposits in the basin contribute significant amounts of phosphate during erosion and runoff, and irrigation return waters are rich in nitrogen and phosphorus. Municipal and industrial discharges also contribute these nutrients.

- *Salinity, Acidity, and Alkalinity.* Widespread irrigation activities in the Snake Basin increase the dissolved solids concentrations of the river; levels in the upper reaches of the river seldom exceed 150 mg/l, but in the middle portion of the river they average 400 mg/l. The range throughout the basin is from 20 to 2,000 mg/l. Acidic discharges (pulp and paper plants, lumber and plywood mills) at Lewiston drive the pH level down to near the legal criterion of 6.5.

- *Oxygen Depletion.* Typical dissolved oxygen concentrations are very close to saturation throughout the entire river. Reductions occur in some reservoirs affected by municipal and industrial discharges. Dissolved oxygen is better today than a decade ago.

- *Health Hazards and Aesthetic Degradation.* The total coliform standard of 1,000 organisms per 100 ml is not often met in free-flowing portions of the river. Values in excess of 5,000 organisms per 100 ml predominate below each population center in the upper river, as well as in the reach between the mouth of the Boise River and Brownlee Pool. No seasonal or long term trends are evident.

GENERAL PHYSICAL DESCRIPTION

The Snake River is the largest of the tributaries of the Columbia River. It drains 109,000 square miles—an area half again the size of New England—and traverses 928 miles from its source in northwestern Wyoming (Figure IX-1). The mean annual discharge of water from the Snake to the Columbia is about 46,000 cfs.

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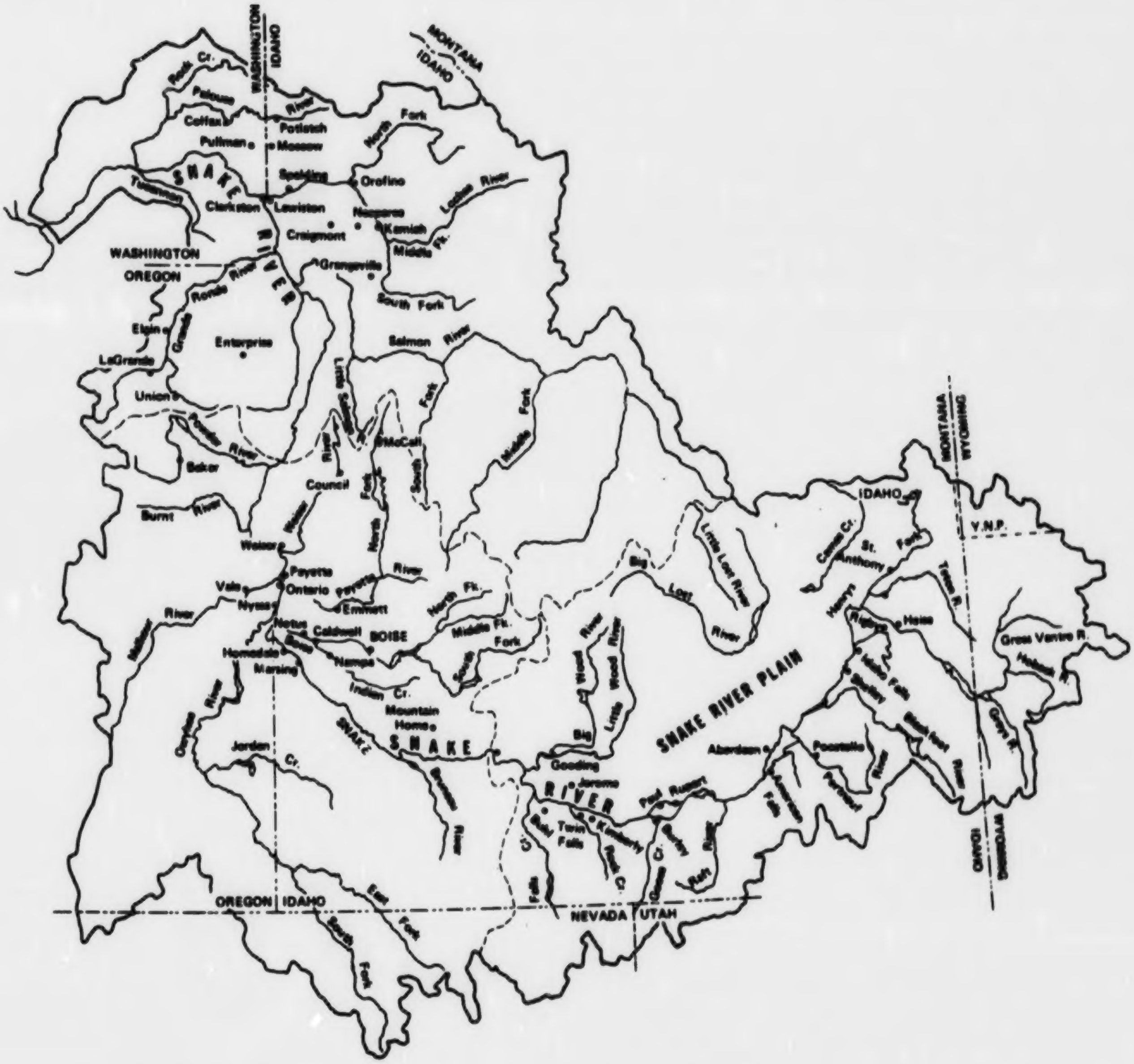
Figure IX-1 AREA MAP SNAKE RIVER



WASHINGTON
IDAHO
MONTANA
IDAHO
Cr.
Palouse
River
Colfax
Potlatch
Pullman
Moscow
North
Fork
SNAKE
Spalding
Orofino
Lochsa River
Tucannon
Clarkston
Lewiston
Nezperce
Craigmont
Kamiah
Middle Fk.
WASHINGTON
OREGON
RIVER
Grangeville
Ronde River
South Fork
Elgin
Grande
Enterprise
Salmon River
LaGrande
Little Salmon
Union
Fork
Fork
Middle
Powder River
McCall
Baker
River
Council
South
Fork
Burnt River
North
Fork
Weiser
Weiser
Payette
River
Vale
Ontario
Payette
Nyssa
Emmett
North Fk.
Malheur
River
Notus
Caldwell
BOISE
Middle Fk.
Fork
Homedale
Boise
Nampa
South
Marsing
Indian Cr.
Owyhee
River
Mountain Home
SNAKE
Jordan
Cr.
Bruneau
River
OREGON
IDAHO
East
Fork
South
Fork
Big
Wood
River
Little
Wood River
Little Lost River
Big
Lost
River
Camas Cr.
St.
Anthony
Fork
Teton R.
IDAHO
MONTANA
WYOMING
Y.N.P.
Henrys
Rigby
Heise
Gros Ventre R.
Hoback
Idaho Falls
Blackfoot
SNAKE RIVER PLAIN
Blackfoot River
Aberdeen
Pocatello
Portneuf
River
Greys R.
Gooding
Jerome
RIVER
Fort Rupert
Twin Falls
Kimberly
Salmon
Falls
Cr.
Rock Cr.
Goose Cr.
Raft
River
Falls
Bannock
NEVADA
UTAH
IDAHO
WYOMING

The Snake is one of the most hydrogically complex rivers in the world. Virtually the entire flow of the first 350 miles of the stream in the upper basin is stored in reservoirs for 7 months and released for irrigation in the remaining 5. Over the next 300 miles in the middle basin, the Snake–renewed by massive groundwater inflows–flows virtually unused through an arid, sparsely populated basin. In its last 300 miles in the lower basin, the river is supplemented by free-flowing tributaries that contribute two-thirds of its flow (Figure IX-2). That larger river passes through a deep, sharply inclined canyon impeded by a series of hydroelectric dams. It is as if, on a smaller scale, the Colorado, Missouri, and Columbia Rivers were laid end to end. Because of that diversity, it is inappropriate to view the Snake as a single stream. It is three distinct hydrologic regimens that create three separate aquatic environments.

The population and economic base of the Snake watershed is essentially rural and agricultural. Population growth, although continuous, has been below the national average since 1940. The rate of industrial growth, however, has been higher than for the Nation as a whole in the same period: food processing, production of phosphate-based chemicals, wood-product manufacturing, and fabrication of agricultural machinery have been the foundations of industrial growth. Secondary industries and expansion of services have stemmed from these industries.

Most of the Snake watershed is mountainous and virtually uninhabitable. Much of the lower plain is semiarid prairie, but its mineral soils are enormously fertile if supplied with irrigation water, and the steep drop of the lower river generates great natural energy that has been harnessed by electric turbines. Thus the social and economic lifeblood of the Snake basin is its water and the system of storage, diversion, transmission, and power generating facilities that have been installed to utilize it.

POLLUTION PROBLEMS AND SOURCES

Not surprisingly, given the high usage of the waters for irrigation, power, and waste discharges, the waters of the Snake have experienced frequent instances of pollution. At Milner Reservoir, these three uses combined to produce the Snake's worst pollution episode of the past decade. From 1960-65, there were four massive fish kills, each involving at least 200,000 fish. The mechanics of the four events were similar in each case. Potato processors at Burley and Heyburn discharged large quantities of organic waste to the reservoir. Ice cover on the surface of the reservoir prevented reoxygenation. Upstream reservoirs, storing for the following irrigation season, allowed no water to pass into Milner Reservoir except for no more than 600 cfs to supply water for the hydroelectric generator upstream at American Falls Dam; on weekends, when electricity demand fell off, there was often no flow at all. The consequences were predictable. Decaying wastes utilized available oxygen supplies, and fish were suffocated. Maintenance of a minimum flow of 600 cfs out of Milner Reservoir and higher levels of waste treatment have averted a recurrence of the situation over the past 6 years.

Nuisance algae blooms occur in all three sections of the Snake River each summer, from Idaho Falls (RM 825) to Brownlee Reservoir (RM 285). The growths cause discoloration and floating mats of algae matter and are most common in reservoirs. The situation seems to be moving progressively downstream and is sometimes manifested below Lewiston and Clarkston (RM 145) on the lower river. Filling of Lower Granite Dam, located below Lewiston, may exacerbate the situation.

The Snake has a number of other pollution problems:

- Dissolved gas supersaturation as severe as that of the Columbia also occurs in the Snake River as a consequence of the turbulent flow over hydroelectric dams in the lower reaches.
- Bacteria concentrations exceed legal criteria over most of the Snake River. Municipal and industrial wastes, as well as runoff, are implicated.
- Turbidity is often excessive in the upper and middle portions of the river. Agricultural practices and reservoir flushing contribute to such localized turbidity.

- Pesticides have been suspected of producing toxic effects; in a few cases, the effects have been documented. The intensively developed agriculture of the upper river and the concentrating impact of American Falls Reservoir certainly create conditions favorable to aquatic toxicity. AEC's National Reactor Testing Station at Arco, Idaho, has been a long-standing source of concern, even though manmade radioactivity had not been detected in the water. And toxic discharges from a chemical plant on a tributary have caused fish kills.

What is noteworthy about the list of pollution problems is their diversity. There is no connecting thread of process, season, trend, or source. Pollution of the Snake has, indeed, been variable and situation-specific.

Nonpoint Sources

The list of nonpoint sources of pollution of the Snake River is long. While it is difficult to say which is most important, it is certainly safe to conclude that, when considered together, they are significant in determining the quality of the stream.

In the mid-1960's reservoir-operating procedures were the prime cause of serious pollution. When the irrigation season ended, storage reservoirs closed and remained closed until a new season began. Considering the vital importance of irrigation to the upper and middle portions of the Snake River, that ultraconservative management system was understandable. Invariably, however, it induced winter drought, followed by minor spring flooding as the snowpack melted with reservoirs filled. The major manufacturing industry of the areas was—and is—food processing, based in large measure on fall-harvested commodities. Thus the massive organic waste discharge associated with beet sugar refining and potato processing occurred during the period of artificial drought imposed by reservoir filling. Some degree of pollution was an annual occurrence in the Snake River below food-processing concentrations at Idaho Falls and Burley, as well as in tributaries. Cooperative arrangements among irrigators, Federal reservoir authorities, and pollution abatement agencies have modified reservoir management procedures to sustain a continuous minimum flow. This, with expanded waste treatment, has helped to avert pollution episodes since the late 1960's.

The reservoir environment itself is inherently favorable to pollution. Reservoirs accumulate and recycle materials. Temperature- and dissolved oxygen-stratification occur. A broad surface area and reduced flow rate promote settling of sediments and absorption of solar energy, favoring development of algae blooms, which tend to be worsened by the reservoir's accumulation of nutrients. The mechanisms are all sharply evident in American Falls and Brownlee Reservoirs and in the Snake's tributaries.

Agricultural practices also promote water pollution in the Snake basin. The disaggregated, mineral soils of the Snake River plain and the Palouse hills are subject to more than normal erosion when vegetative cover is disturbed. Dry farming, winter fallow, and excess water application with ridge and furrow irrigation aggravate erosion and lead to sediment and turbidity in waters. Readily soluble nitrogen is picked up by runoff, and pesticides and phosphorus, which have a high affinity for soil, are carried to watercourses by sediments.

Over 10 million beef and dairy animals, about 700,000 sheep, and half a million chickens are found in the Snake watershed, most of them concentrated from Idaho Falls to Twin Falls along the upper river and in the area of the Boise River valley. At any given time, more than half of these animals will be found in 50 or fewer closely concentrated feedlots, supported by the area's forage crops and by-products of food processing. Such animal concentrations may, in periods of high runoff, become significant sources of bacteria, sediments, nutrients, and oxygen-demanding materials.

Properly controlled irrigation is generally beneficial to water quality. First, irrigated soils tend to be more stable and resistant to erosion than dry farmed soils. Second, subsurface return flows—cooled, filtered, and generally possessing the characteristics of spring water—usually are of better quality than the surface waters they enter. Nonetheless, excessive irrigation, which promotes erosion, particularly on slopes, has frequently occurred in the Snake basin. Although there are no firm rules, careful nonerosive irrigation is easier with sprinkler methods than the gravity-surface methods that predominate in the Snake River watershed (Table IX-1). Water rights laws, as well as

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technological factors, are implicated in the pattern of abuse. Since water rights have enormous economic value, the individual farmer has a strong practical incentive to overuse water in order to maintain his rights, even at the expense of some marginal loss of short-run productivity.

There are other potentially polluting aspects of irrigation, but these have been averted by natural conditions and good management. On other rivers, massive irrigation has completely altered the natural hydrologic cycle, severely reduced the quantity of surface water, and increased salinity and mineralization. On the Snake, however, the water management regimen has been adapted to ease environmental stress. Although flows are managed in a fashion that levels the spring flood and moves it into summer, a constant annual flow is provided. Water supplies are not depleted, even though substantially all the flow of the upper river is used in irrigation, because massive groundwater inflows to the Snake renew it just below the point of final diversion. Thus, although a third of the mean annual flow of the upper river is consumed by evapotranspiration, neither excessive mineralization nor the other damaging consequences of extreme low flow are experienced.

TABLE IX-1

SNAKE RIVER IRRIGATION ACTIVITY (1964)

	Acres irrigated		Acre-feet of water	
	By sprinkler	By gravity	Diverted	Consumed
Upper basin	479,000	2,006,000	13,541,000	4,920,000
Middle Basin	119,000	1,346,000	6,370,000	2,975,000
Lower Basin	61,000	215,000	1,085,000	533,000
Total	659,000	3,567,000	20,996,000	8,428,000

Point Sources

There are 43 significant point sources discharging wastes directly to the Snake River (Table IX-2). These include 20 municipalities, one pulp and paper plant, 11 potato-processing plants, two sugar refineries, and nine other factories (mostly food processors). In addition, the National Reactor Testing Station discharges some 1.3 billion gallons per day of cooling water to the soil through deep well injection and seepage ponds.

Because of the predominance of the wastes of food processors harvesting in the fall, there is a definite seasonal pattern to waste discharges (Table IX-3). At the processing peak, 176,000 pounds of BOD_5 are discharged daily to the Snake River, almost four times the off-season discharge.

The processing season varies, but it is most concentrated from October to March. The season comes, then, at the period of storage-induced low flows, when it can be expected to have maximum impact. Moreover, 70 percent of the total Snake loading occurs on the upper river, where only 7 percent of the total streamflow is developed. (Indeed, 18 percent of the total discharge occurs in the 21 miles of stream between Minidoka Dam and Milner Dam.)

Primary or secondary levels of waste treatment are employed by most municipal and industrial dischargers. The state of Idaho has focused its water pollution abatement efforts on the Snake and Boise Rivers, and since 1959 the number of waste treatment plants and the degree of treatment have expanded annually, more than compensating for the expansion of potato processing and sugar refining. All municipalities discharging to the Snake treat their wastes,

TABLE IX-2

SNAKE RIVER: POINT WASTE DISCHARGES (1972-73)

Discharger	River mile	Flow (m.g.d.)*		BOD$_5$ (lb./day)		Phosphorus (lb./day)	
		Sewage	Industry	Sewage	Industry	Sewage	Industry
Clearwater Beverages	135		0.01		237		1.1
Potlatch Forests	135		64.46		15,982		23.4
Smith Frozen Foods	135		0.01		232		1.9
Twin City Foods	135		0.01		429		2.8
Lewiston	135	2.20		2,508		196	
Lewiston Orchards	135	0.97		1,646		93	
Clarkston	138	0.59		777		58	
Asotin	146	0.04		51		6	
Lower River		3.80	64.47	4,982	16,880	353	29.2
Oregon Portland Cement			NA		NA		NA
Weiser	351	1.00		591		36	
Fruitland	362	0.90		202		13	
Ontario	368	2.70		135		52	
Ore-Ida Foods	368		2.85		12,969		NA
Nyssa	389	0.27		265		20	
Amalgamated Sugar	389		NA		15,389		NA
American Fine Foods	389		0.35		NA		NA
Oregon Concrete Products	389		0.01		0.03		0.05
Wildex	410	0.05		136		5	
Marsing	424	0.10		47		5	
Glenns Ferry	539	0.12		18		11	
Middle River		5.14	3.20	1,394	28,358	142	NA
Twin Falls	609	NA		8,120		195	
Paul	647	0.09		54		NA	
Ore-Ida Foods	649		6.3		8,224		580
Bryant Meat	650		NA		NA		NA
Burley	653	0.80		170		42	
Heyburn	653	0.10		280		11	
J. R. Simplot	654		7.3		20,800		456
Rupert	665	1.50		2,600		160	3
A&P	684		0.8		450		
Reuger Hatchery	712				205		11
American Falls	714	NA		180		36	
Blackfoot	762	0.70		2,070		51	
American Potato	763		2.0		15,484		42
Idaho Potato Starch	764		0.3		3,500		31
Shelley	787	0.10		15		5	
R. T. French	788		1.0		140		29
Idaho Falls	797	5.30		7,290		610	
Idaho Potato Starch	798		0.50		9,000		150
U&I Sugar	799		5.3		5,300		12
Rogers Brothers	799		1.5		18,681		85
Western Farmers	800		1.0		17,700		131
Idaho Potato Foods	804		0.7		3,500		30
Gold Valley Pack	813		0.3		215		24
Upper River		8.59	27.0	20,779	103,199	1,110	1,584
Basin total		17.53	94.7	27,155	148,437	1,605	1,617

*Million gallons per day.

TABLE IX-3

SNAKE RIVER: POINT SOURCE BOD_5 LOADS BY SEASON (1972-73)

	Food-processing season	Off season
	(pounds BOD_5/day)	
Upper river	124,000	22,000
Lower river	21,900	21,900
Middle river	29,800	1,400
Snake River	175,700	45,300

often also treating the wastes of the smaller food processing plants. Lagoons are the predominant method of treatment. Industrial waste treatment also makes heavy use of land-intensive methods, including spray irrigation and evaporation ponds.

The effectiveness of industrial treatment efforts is indicated by the 50 percent reduction of BOD_5 discharges that has occurred since 1965 (Table IX-4). Industrial waste treatment was already fairly generally available in that year. Mean calculated BOD_5 removal for classes of dischargers in the Snake River basin in 1965 was: municipal, 59 percent; sugar refiners, 47 percent; potato processors, 55 percent; all industrial dischargers, 46 percent.

For several reasons, reduction of municipal waste discharges in the same period is believed to have been significantly less. Municipal treatment was relatively better in 1965: 59 percent BOD_5 removal versus 46 percent for industrial treatment. Industry has tended to connect to public sewers, increasing total municipal waste discharge. The sewered population has increased significantly. Although the aggregate reduction in municipal waste strength is probably well under that of industrial wastes, it has been quite creditable (Table IX-5).

DATA AND METHOD

Water quality data for the Snake River have been collected for a series of special studies, but they are by no means as plentiful as might be desired. Cooperative State/Federal surveys were conducted in the winters of 1962 and 1963, and the summers of 1963, 1964, and 1965. EPA's National Field Investigation Center (NFIC) in Denver surveyed reaches from Twin Falls to Brownlee Reservoir in 1971. EPA Region X conducted seasonal surveys of the reaches above Twin Falls in 1971. There are national water quality network stations at Weiser and Wawawai on the lower river; and EPA's predecessor agency maintained a continuous automatic water quality monitor in Milner Reservoir during 1968-69. Special analyses of irrigation return flow quality, pesticide residues, and reservoir behavior have been conducted in the Snake River basin by EPA, the U.S. Bureau of Reclamation, and Washington State

TABLE IX-4

SNAKE RIVER: INDUSTRIAL BOD_5 DISCHARGES

	1965	1972
	(pounds BOD_5/day)	
Potato processing	150,600	110,500
Sugar refining	68,300	20,700
Pulp and paper production	78,000	16,000
All major industries	296,900	147,200

University. Oregon and Idaho maintain increasingly active water quality surveillance stations on the river and some of its tributaries.

Basic sources for this chapter are:

- Data derived from the activities described above, most of which are available in EPA's STORET system.
- The two-volume NFIC analysis of the Snake River from Twin Falls to Brownlee Reservoir.
- An interpretive monitoring study of the upper river prepared by EPA Region X.
- An unpublished comprehensive water quality management plan for the Snake River basin produced by the Federal Water Pollution Control Administration in 1966.

While these sources are sufficient to understand the general quality of the Snake River, there are gaps (Table IX-6). The condition of the upper river, where pollution has been most prevalent, is much better understood than that of the middle and especially the lower river. Biological data are generally deficient.

The analytical method and format employed for the Snake River are described in Chapter I, with the exceptions that only median quality variables are employed in most instances, because of insufficient data to depict quality at 15th and 85th percentiles, and trends are analyzed by comparing 1971-72 conditions with those of 1964-65.

Mathematical modeling of stream dynamics was important for this analysis. Dissolved oxygen models and phosphorus models were developed for the entire river in 1965, and more detailed phosphorus balance relationships were compiled for the upper river in 1972.

TABLE IX-5

TRENDS IN MUNICIPAL TREATMENT IN IDAHO

	Sewered population of Idaho		
Waste treatment	1963	1968	1973
None or minor	42,400	18,400	13,000
Primary	142,400	147,000	155,800
EPA secondary*	18,200	33,000	51,900
Non-EPA secondary†	100,000	165,400	212,100
Total	303,000	363,900	432,800
Mean BOD$_5$ reduction	50%	61%	64%

*Defined by EPA regulation as the more stringent of either: (1) 85 percent removal of influent BOD$_5$ and suspended solids, or (2) an effluent of no greater than 30 mg/l of BOD$_5$ and suspended solids.

†Defined as plants that use a biological stage to reduce the oxygen demand of organic materials, but do not meet EPA standards. These include plants that either treat a significant amount of concentrated industrial wastes or use lagoons for biological treatment. Both circumstances predominate in the Snake River Basin.

TABLE IX-6

SNAKE RIVER BASIN: MONITORING REQUIREMENTS

	Data uses				Data available
	Water quality trends	Waste load allocation	Modeling	Water quality standards	
Physical					
Receiving water		X	X		Yes, except middle basin
Reservoirs		X	X		Yes
Outfall information		X	X		Yes, except middle basin
Tributaries & diversions		X	X		Yes, except middle basin
Groundwater accretion		X	X		Yes
Water quantity					
Streamflow	X	X	X		Yes, except middle basin
Stage, tide					
Point-source discharge		X	X		No
Nonpoint source discharge		X	X		No
Lake & reservoir water levels	X	X	X		Yes
Water quality					
Carbon	X	X	X	X	Partial, no trends
Nutrients	X	X	X	X	Partial, no trends
Metals	X	X	X	X	Partial, no trends
DO, temperature, pH, and conductivity	X	X	X	X	Partial, no trends
Pesticides	X	X	X	X	Partial, no trends
Transfer ratio		X	X	X	Yes, except middle basin
Biological					
Phytoplankton & zooplankton	X				Partial
Benthic macroinvertebrates	X				Partial
Microorganisms	X	X	X	X	Partial
Algal & bioassays	X	X			Partial
Sediments					
Chemical composition	X	X	X		Partial, lower basin only
Particle size	X				Partial, lower basin only
Pesticides	X				No
Transfer ratio		X	X		No

WATER QUALITY CONDITIONS

Harmful Substances

Gas Supersaturation. Dissolved gas concentrations in excess of 110 percent of saturation have been measured not only below Ice Harbor, Lower Monumental, and Little Goose Dams, where spring spilling is a perennial result of flood stages of the uncontrolled Salmon and Clearwater Rivers, but even below Brownlee, Oxbow, and Hells Canyon Dams, which are well above the major tributaries. The persistence of toxic conditions affects Snake River salmon runs that may extend from February through June from RM 285 to the mouth, as well as reinforce the supersaturation of the receiving Columbia River.

Radioactivity. Radioactive contamination of ground or surface waters has been feared since the start-up of the National Reactor Testing Station. Those fears, however, have not been substantiated. Neither the AEC, which maintains an extensive monitoring network, nor independent sources have discovered excessive radioactivity in the

Snake River or the great groundwater aquifer underlying the Snake Plain. The maximum gross beta count discovered in on-site production wells was in the neighborhood of 125 pc/1, about six times the highest detected in off-site monitoring wells.

Pesticides. Pesticides have constituted a continuing source of potential toxicity in the waters of the agriculture-dominated upper and middle portions of the Snake and in its tributaries. Even in September 1973—long after flood stage, near the end of the growing season, and with all the regulatory restrictions applied to pesticides over the past 5 years—an EPA survey found detectable levels of some pesticides at eight of nine upper basin locations where water samples were taken (Table IX-7). Presence of pesticides at these levels in the water probably means that they are accumulating in the food chain at levels that could be lethal. The highest levels of lindane and DDT were found in the Snake River below Minidoka and American Falls Reservoirs, lending strong circumstantial evidence to the long-held hypothesis that reservoirs accumulate toxins.

In August 1966, during water quality sampling survey of the upper basin, the Federal Water Pollution Control Administration found dead adult fish on the banks beside the forebay of the powerhouse at American Falls Dam and again at a location below the outlet of the waste treatment works for the City of American Falls, some distance below the dam. Dead fish are common along these banks because fishermen are in the habit of killing trash fish. The presence of several good-sized adult trout, however, was puzzling. A dozen dead fish from each location were analyzed. In every case, pesticides were found—not just in the liver and viscera, where they usually concentrate, but throughout the flesh of the fish (Table IX-8). Levels generally were found to be sufficient to have killed the organism. Indeed, the high concentration occurring in so many fish prior to their deaths led biologists to speculate there had been several generations of genetic specialization acting to produce the animals, with all but the most resistant strains already eliminated by waterborne toxicants.

Reservoir accumulation of pesticides is considered to be particularly damaging because of temperature-related metabolic mechanisms. Normally, chlorinated pesticides are not metabolized, but stored in the fats of living animals. While Snake River reservoirs are covered with ice for several months, the fish, their life processes retarded in a state of quasihibernation, slowly draw on their accumulated reserves of fat. Pesticide residues accumulate in increasingly higher concentrations in the diminishing store of fats. The breakup of ice cover, reservoir turnover, and sudden warming of the water column accelerate life processes and tend to coincide with depletion of stored fats. At precisely the point that a fish has least resistance, his biological system receives the shock of delivery of the accumulated toxins. The extent to which this imposes pressure of fish populations is unknown, but may be significant.

TABLE IX-7

SNAKE RIVER: PESTICIDES IN UPPER BASIN (September 1973)

Location	Lindane	DDE	DDT
		(micrograms per liter)	
Henrys Fork, above St. Anthony	.002	.001	.001
Portneuf River, Siphon Rd.	.002	.003	.003
Snake River, below Minidoka Dam	.003	.001	.010
Main Drain, 950 W. Rd.	.002	.002	.002
Snake River at Milner Dam	.001	.001	*
Snipe Creek	*	.001	.001
Spring Creek 5 miles E. of Burley	.001	.004	.001
Drain, S. of Rupert	*	*	*
Main Drain, E. of Rupert	.001	.002	.002

*None within limits of detection.

TABLE IX-8

PESTICIDE CONCENTRATIONS IN DEAD FISH TAKEN NEAR AMERICAN FALLS DAM (1966)

Pesticide	Fish collected near powerhouse		Fish collected below dam	
	Liver and viscera	Whole fish	Liver and viscera	Whole fish
	(average parts per billion)			
DDE	350	784	420	40
DDD	124	180	320	20
DDT	–	–	32	10
Chlordane	195	183	377	–
Dieldrin	56	14	34	5
Endrin	2	2	–	2

Physical Modification

The Snake River no longer resembles its natural condition. The flow pattern and physical channels have been almost totally altered in the upper river by a succession of storage and transmission works devoted to irrigation. In the lower river, hydroelectric dams have increased the average depth. Flows are not only shifted in time but are actually reduced by the evaporation that occurs during extensive irrigation, an effect that is most apparent on the upper river.

Sediment Production. Sediment and suspended materials result in turbidity at many points along the Snake. Spring floods in the lower river cause turbidity to reach objectionable levels; reservoirs alleviate the situation somewhat by promoting sedimentation. Along the upper and middle rivers, disaggregated soils and strong winds produce significant erosion; the effects of natural forces are supplemented by the intensive agriculture of the Snake plain. A more specific source of turbidity is surging releases from American Falls Reservoir during the irrigation season. The releases scour the bottom of the reservoir as it is evacuated, resuspending significant quantities of organic and inorganic materials.

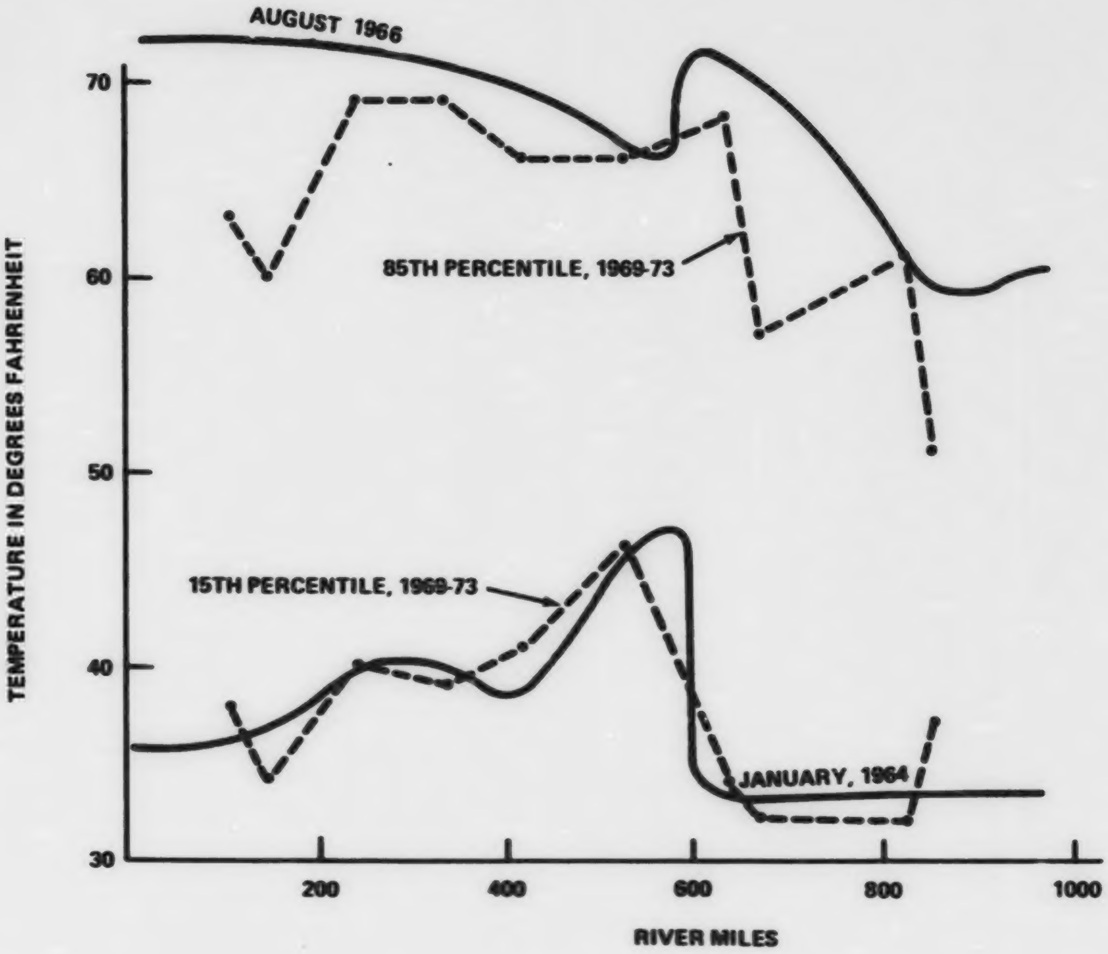
Temperature. The temperature of the Snake, although subject to many influences, varies in rather consistent patterns. Winter temperatures are generally close to freezing, except in areas where flow is derived largely from groundwater. Small reservoirs in the upper basin freeze over annually, and icing is moderate at other ponded locations. The rising temperature of summer months is reflected in different degrees at different locations. Near the headwaters, flows derived from meltingsnows remain below 60°F throughout the year. Downstream, warming results from solar radiation and is accelerated by the effects of impoundment, streamflow depletion, and irrigation return flows. Below Twin Falls, temperatures are moderate throughout the year, since most of the flow is derived from springs. Snow-fed flows of the major tributaries in the lower basin cool the main stem waters that have been warmed by use and solar radiation. The most significant temperature increases are recorded in the central basin tributaries that are widely used for irrigation. There, flow depletion due to storage and diversion, and the surface return of irrigation waters warmed on fields, act together to raise prevailing temperatures. (Subsurface return flows are normally cooler than receiving waters.) A similar situation exists in the main stem Snake in the upper basin, where almost complete utilization of flow for irrigation accelerates warming of the stream.

No change in the temperature regimen can be discerned in data covering the past 10 years. Two influences, air temperature and the massive groundwater inflows below Twin Falls, appear to predominate. The warming effects of reservoirs, while discernible, are slight. Also, winter temperatures increase for a short distance below each principal population concentration along the river (Figure IX-3).

Figure IX-3 **RIVER PROFILES**

SNAKE RIVER

EXTREME TEMPERATURES



Eutrophication Potential

There can be no question that the Snake River has excessive biological productivity, nor that some degree of eutrophication has been produced in its reservoirs. The evidence is apparent in the color of the water, the abundant floating growths, the rooted plants in its shallow waters, the masses of slimes that clog irrigators' siphons and headgates, the growths that cling to rocks and structures, and even in the greenish tinge of the water skier who has taken a fall in American Falls Reservoir.

Excessive biotic production is so complex that quantitative descriptions are difficult. One simple measure of the phenomenon is the difference between daytime and nighttime levels of dissolved oxygen. During the day, plants give off oxygen as waste; at night, they utilize oxygen. Thus eutrophic or excessively productive waters are characterized by oxygen supersaturation during the day and low levels at night, especially in summer, when production of biota and sunlight peak.

Supersaturation of dissolved oxygen on the Snake is most marked in the stream reach from American Falls Reservoir to Brownlee Reservoir, with saturations fluctuating 30 to 40 percent in a 24-hour period (Figure IX-4). But even the radical fluctuations of that reach are exceeded in some tributaries: a range of 60 to 125 percent of saturation in a 12-hour period has been documented in the Boise River, and similar swings can be assumed on the Portneuf, Blackfoot, and perhaps other tributaries. In depths of reservoirs, nighttime values are below legal standards for dissolved oxygen.

Excessive productivity is heightened in ponded waters. Broader surface area and reduced turbidity result in increased surface temperature and deeper light penetration, thus allowing fuller utilization of available nutrients and increasing the production of biota. As the organisms die, they settle and decompose in the relatively still waters, consuming oxygen and enriching the lower strata of the water column.

At American Falls Reservoir, nutrient buildup does not seem to be a serious problem because the enriched waters are evacuated annually for irrigation. However, there is a large potential phosphorus load incorporated in bottom muds. In Brownlee Reservoir, persistent materials do accumulate, although the rate has not been calculated. The reservoir is deep enough to be thermally stratified. Surface temperature changes in spring and fall induce reservoir turnover. Thus, at each fall some portion of the summer's accumulation of nutrients becomes available near the surface at a time when light and temperature conditions are still favorable to algae blooms. The process is now taking place with growing intensity in the reservoirs below Brownlee, resulting in nuisance blooms behind Oxbow and Hells Canyon Dam and downstream to the Lewiston area. Certainly, conditions are favorable to the gradual creation of a chain of eutrophic reservoirs through the lower river, each reservoir acting as a trap for the biomass and nutrients that escape the one above.

There can be no doubt that the Snake is naturally an enormously productive stream, a conclusion supported by written records of a century and a half ago. So far as is known, the first literate viewers of the upper river were members of the Astor party, and Washington Irvings's *Astoria* notes that on October 18, 1811, "In the course of the day the little squadron arrived at the confluence of Henry and Mad [i.e. Snake] Rivers, which, thus united, swelled into a beautiful stream of a light pea-green color." Subsequent 19th century travelers also wrote about the river's color, thus verifying the river's algal productivity long before the first waste discharge entered the stream.

But if the Snake is a vigorous producer of algae, man's construction of reservoirs has made that productivity a source of problems. What is far less certain is his impact on nutrient supplies. Nitrogen data are available only for the reaches above Brownlee Dam. Mean concentrations over most of that reach are well in excess of the theoretical thresholds for producing nuisance algae blooms. The principal source of nitrogen is groundwaters entering in the Thousand Springs area below Twin Falls, where concentrations typically increase by a factor of four. Concentrations are especially low in summer in the area from the confluence with the Henrys Fork through Milner Dam—that is, the time and place of maximum biotic production. There is also a slight summer reduction in Brownlee Reservoir. This pattern suggests that there is always more than enough dissolved nitrogen in the Snake to support algae production (Figure IX-5).

Figure IX-4 **RIVER PROFILES**

SNAKE RIVER

DIURNAL FLUCTUATION IN SUMMER DISSOLVED OXYGEN AT SELECTED STREAM POINTS

(1965-66 DATA)

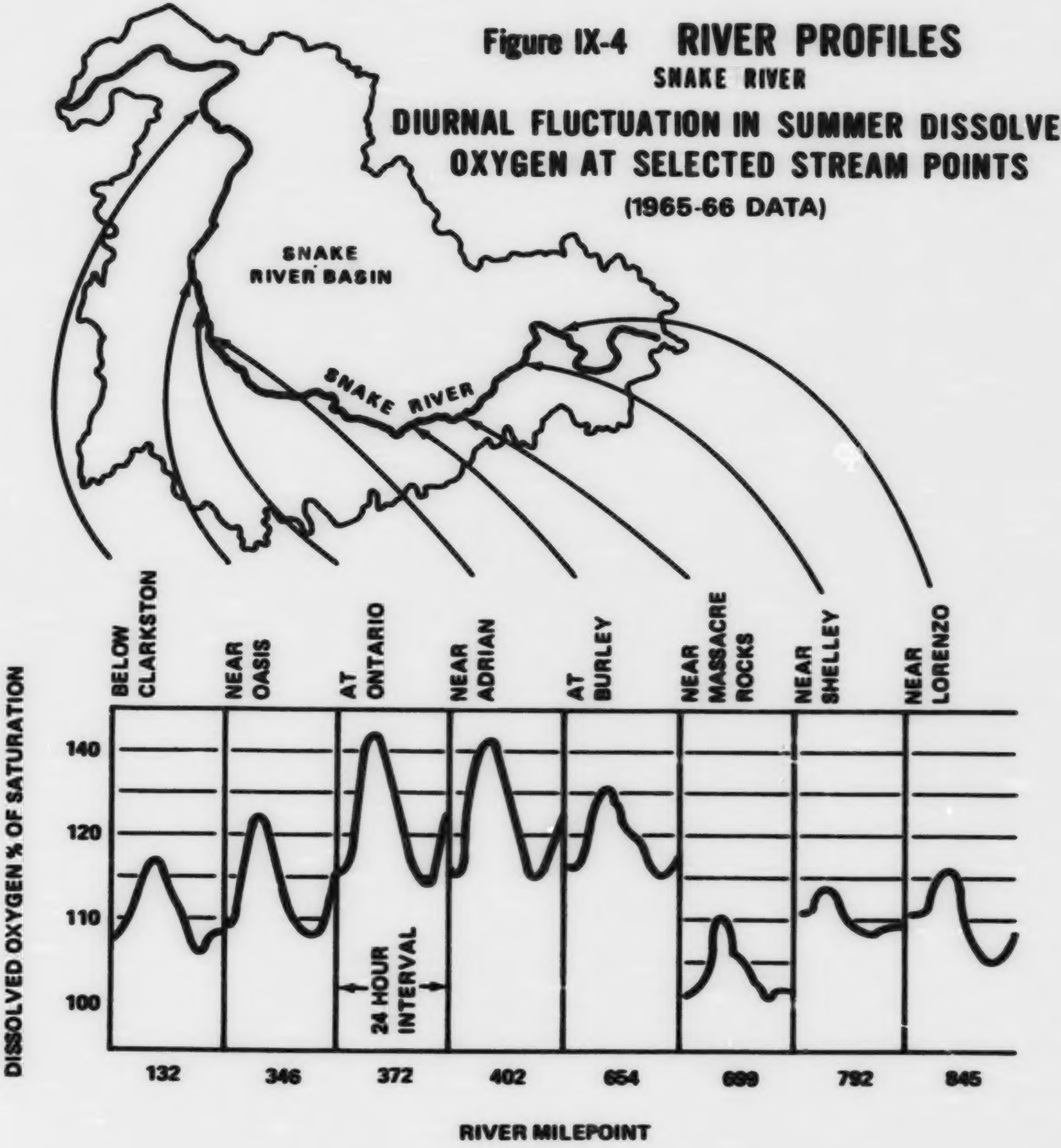
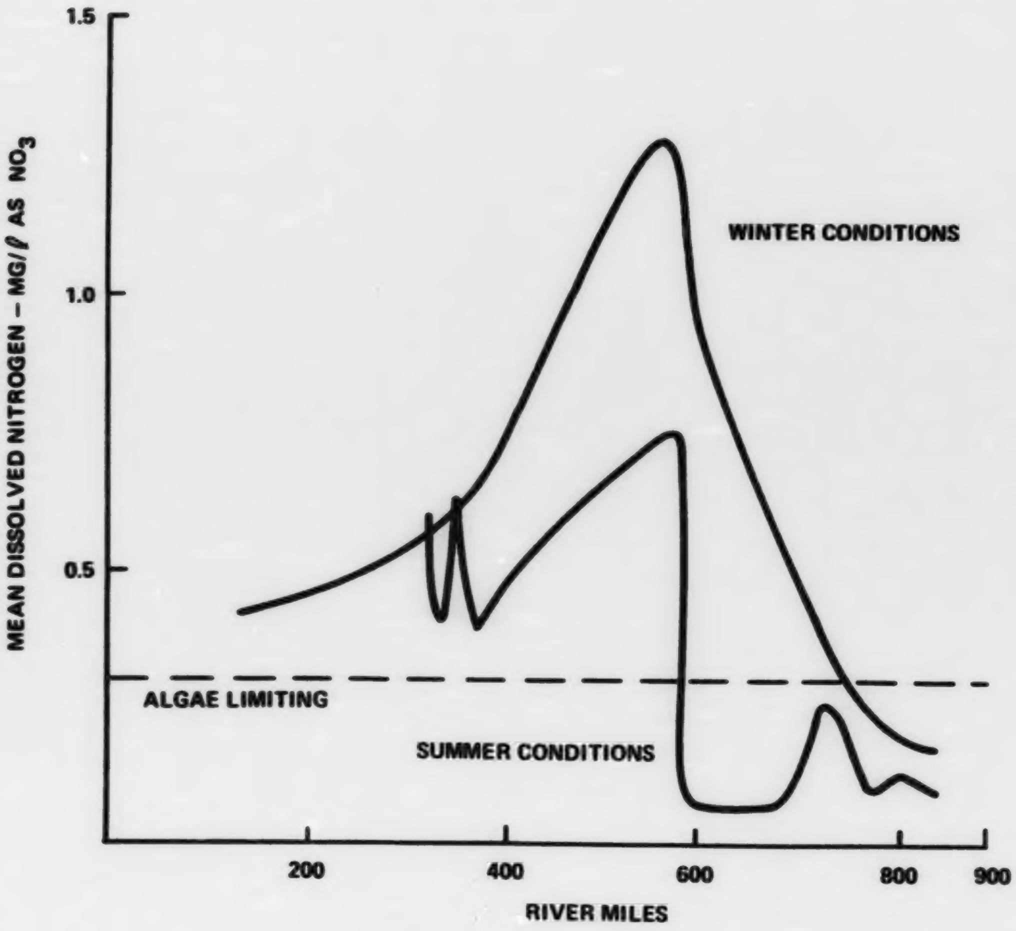


Figure IX-5 **SEASONAL RIVER PROFILE**

SNAKE RIVER

DISSOLVED NITROGEN



The data on trends are inconclusive, except in the lower river, where supersaturation of dissolved gases, including nitrogen, has followed construction of dams.

The mountains that rim the southeastern border of the Snake River basin and form its headwaters contain phosphate deposits that are among the world's richest. Natural leaching of phosphorus from those deposits unquestionably constitutes the basis for the extraordinary productivity of the Snake system, although human activities have added to the rate of phosphorus transfer. How significant that induced alteration may be, however, cannot be assessed at this time.

Phosphate concentrations exceed the theoretical 0.05 mg/l algae-limiting concentration in 50 percent of the observations taken from the mouth of the Portneuf River (head of American Falls Reservoir) to the mouth of the Snake. From the Portneuf to the Thousand Springs, the algae-limiting level is exceeded in 85 percent of the observations. Dilution provided by the Thousand Springs (which are rich in dissolved phosphorus but free of phosphorus-containing suspended matter) pulls the concentrations down briefly, but they soon recover to well above 0.05 mg/l and are sustained over the remaining length of the river (Figure IX-6).

On an annual basis, the Snake delivers 20,000 to 25,000 pounds of phosphorus per day to the Columbia. At the mouth, that load is extraordinarily constant, with the exception of a spring peak that may be attributed to the first flush of snowmelt and to reservoir turnover (Figure IX-7). Upstream, the annual fluctuations are much different:

- At Milner Dam on the upper river, total phosphorus concentrations are fairly uniform, apparently affected little by discharges or runoff.
- At Weiser, in the middle Snake, concentrations rise with spring flows, but peak with low flows that occur at the height of the irrigation season—an apparent sign of point sources.
- At Lewiston on the lower river, partial data indicate a runoff-related peak with the early spring flush (Figure IX-8).

These conclusions are not as clear-cut as they would be on other rivers, however. For much of the Snake, runoff intensity is not governed by precipitation or snowmelt, nor does it correlate with streamflow, because irrigation shifts the relationship: runoff can be artificially induced by irrigation that also reduces streamflow. Thus the apparent point source effect at Weiser is probably related to irrigation runoff, as well as groundwater and point sources. Similarly, the constant levels of phosphorus found at Milner Dam probably result from settling of sediments in upstream reservoirs (American Falls and Lake Minidoka).

Dissolved phosphorus is a more direct measure of nutrient availability than total phosphorus. The rule of thumb is that a dissolved phosphorus concentration of 0.01 mg/l is compatible with nuisance quantities of algae. That level is met or exceeded over the whole length of the Snake River. A review of total and dissolved phosphorus values (as the means of recorded concentrations at consecutive points over the past 5 years) indicates:

- The Snake River's phosphorus content is higher downstream than upstream.
- There is enough phosphorus to support nuisance growths throughout the river.
- The dissolved fraction is consistently a significant portion of the total.
- There appear to be four distinct phosphorus transport regimes in the river (Table IX-9).

From the headwaters to the confluence with the Portneuf River and the head of American Falls Reservoir, concentrations of both total and dissolved phosphorus are quite constant—about 0.03 and 0.015 mg/l, respectively. The Portneuf is the largest single source of phosphorus in the watershed, and its entry raises concentrations in the Snake by about 50 percent. In reservoirs behind American Falls and Minidoka Dams, total phosphorus concentrations decline slightly, presumably as a function of sedimentation, but dissolved phosphorus concentrations

Figure IX-6 RIVER PROFILE

SNAKE RIVER

TOTAL PHOSPHORUS

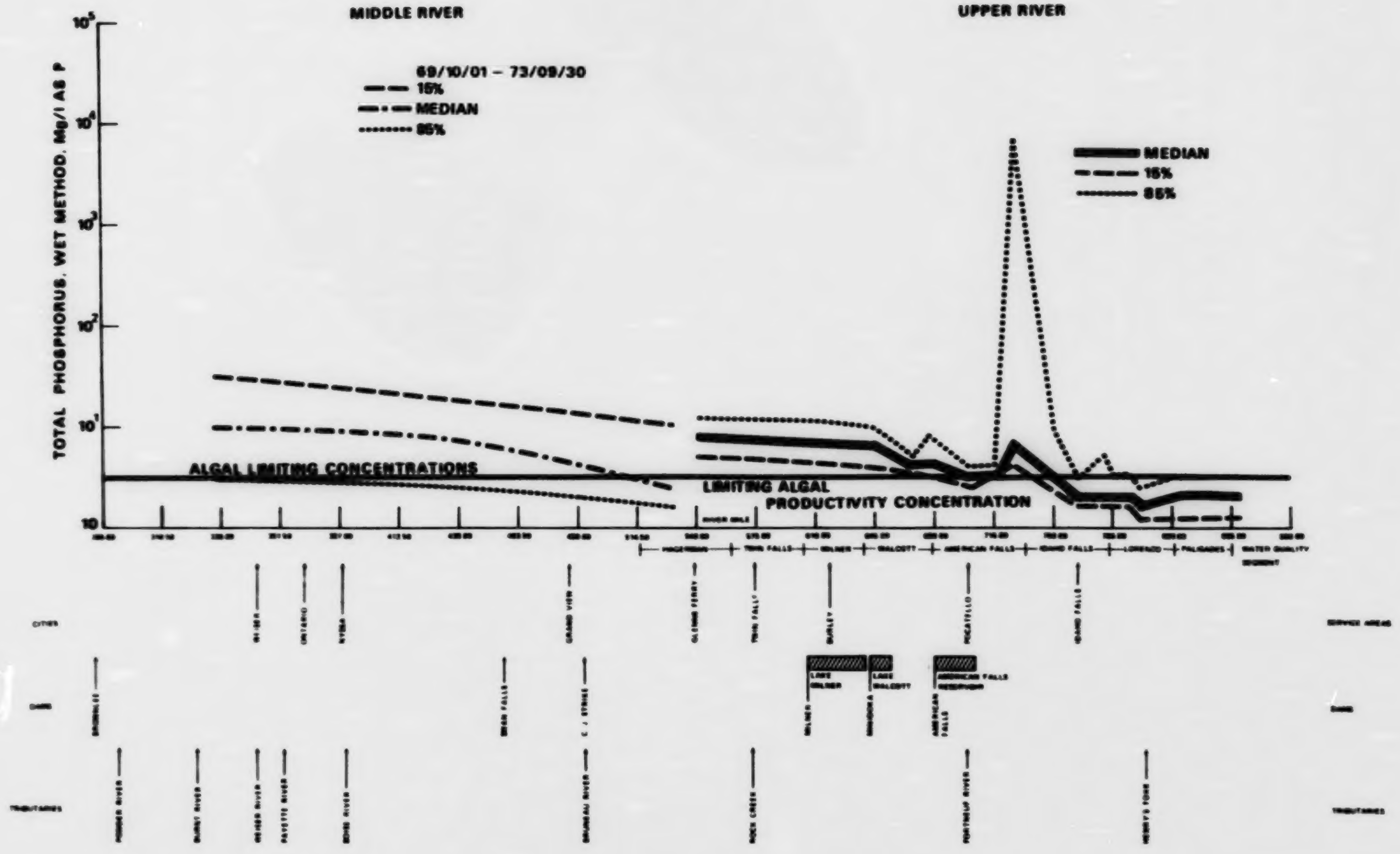


Figure IX-7 TIME TRENDS

SNAKE RIVER

FLOW AND PHOSPHORUS LOADING NEAR THE MOUTH

MONTHLY AVERAGES (1962-65)

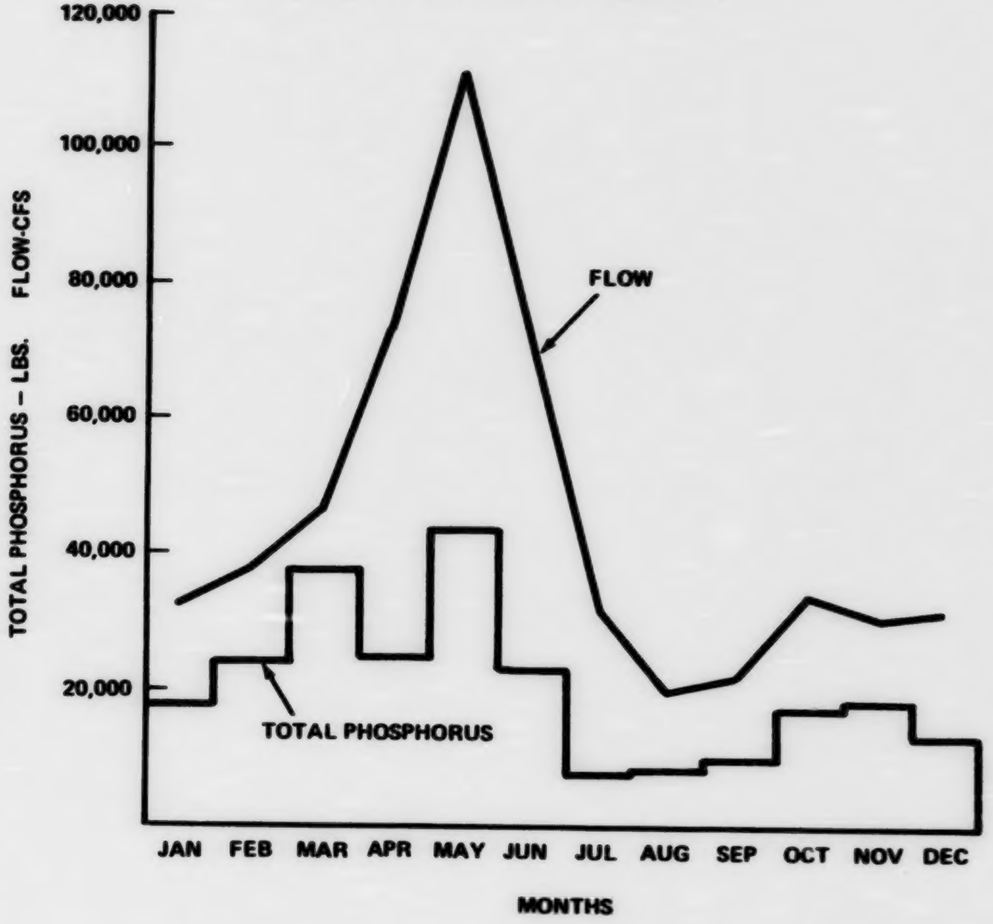
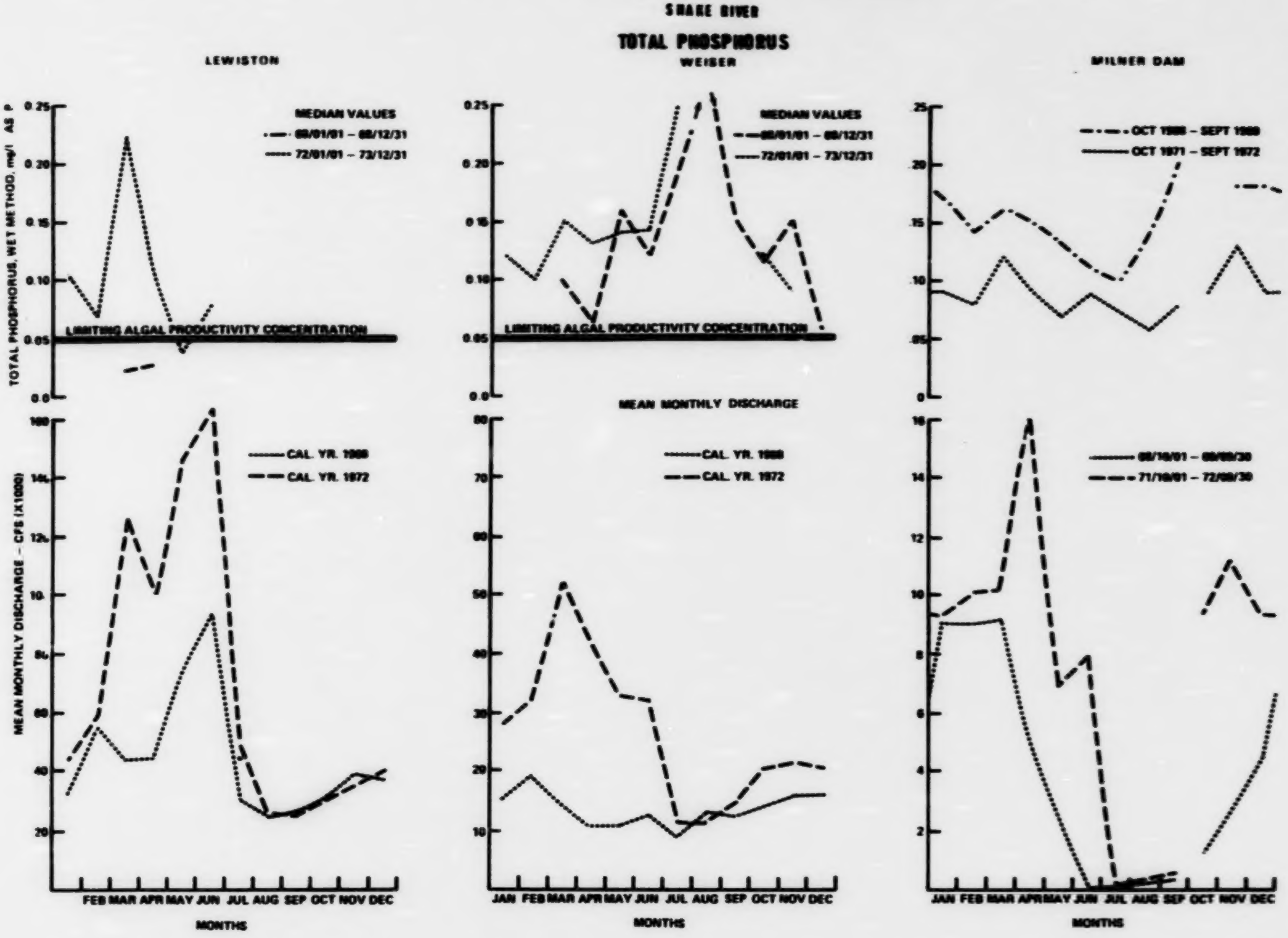


Figure IX-8 TIME TRENDS AT RIVER MILEPOINTS



SNAKE RIVER

TOTAL PHOSPHORUS

TABLE IX-9

SNAKE RIVER: TOTAL AND DISSOLVED PHOSPHORUS CONCENTRATIONS (1969-73)

Location (moving downstream)	Mean phosphorus concentrations		Indicated soil/biomass fraction
	Total	Dissolved	
		(mg/l)	
Below Palisades Dam	.04	.01	.03
Above Henrys Fork	.03	.01	.02
Confluence W. Henrys Fork	.04	.015	.025
Idaho Falls	.02	.01	.01
(below potato processor)	.03	.01	.02
Above Blackfoot River	.03	.013	.017
Below Blackfoot River	.03	.017	.013
Above Portneuf River	.04	.015	.025
Confluence W. Portneuf	.06	.02	.04
Below American Falls Dam	.03	.015	.015
Below Minidoka Dam	.05	.02	.03
Burley Heyburn area	.06	.03	.03
Below Milner Dam	.09	.03	.06
Along Thousand Springs	.05	.03	.02
Below Thousand Springs	.09	.03	.06
Above Boise River	.08	.02	.06
Weiser	.14	.03	.11
Below Brownlee Dam	.07	.04	.03
Below Oxbow Dam	.09	.04	.05
Above Lewiston	.07	.03	.04
Below Lewiston	.14	.04	.10
Below Ice Harbor Dam	.09	.04	.05

are constant and somewhat higher than in the reach above. Dissolved phosphorus concentrations rise another 50 percent in the extended reach of river that spreads from lower Milner Reservoir to the headwaters of Brownlee Reservoir. Total phosphorus concentrations in the reach vary with the balance of offsetting forces of erosion and sedimentation. In the lower river—the reaches below Brownlee Dam—total phosphorus concentrations vary in much the same range as in the reach above, but dissolved phosphorus increases by 0.01 mg/l. The areas of maximum biotic production are between the mouth of the Portneuf River and Brownlee Dam, or well above the areas of maximum phosphorus loadings.

Sources of phosphorus are difficult to determine. Given the mean daily flow of 46,000 cfs and mean concentrations at the mouth, one can estimate that more than 22,000 pounds of phosphorus per day are carried into the Columbia by the Snake—10,000 pounds in solution and the remainder in biomass or as a fraction of soils. Direct sewage discharge to the Snake River amounts to roughly 1,600 pounds per day, and an equal amount is discharged to tributaries, almost entirely in solution initially, although some is converted to biomass. Another 1,600 pounds per day come from direct industrial discharge, with 800 to 1,000 pounds from industrial discharges to tributaries.

The largest single source of phosphorus is the Portneuf River, which carries a loading of 800 to 1,000 pounds per day to the Snake. Two phosphate processing plants at Pocatello alone discharge 350 to 550 pounds per day. Phosphate mining in the upper portion of the watershed and fallout from air emissions of the two plants may also be significant sources of waterborne phosphorus.

The role of irrigation in phosphorus availability may be critical, but it is little understood. Substantially all of the water of the upper Snake is used in irrigation, as is the water of central Snake tributaries. These are the waters that are excessively productive, and the irrigation season overlaps the period of excess production.

In 1972, the U.S. Bureau of Reclamation and EPA studied the quality of irrigation waters in southeastern Idaho (Table IX-10). The study found that:

- Irrigation waters are of uniformly high phosphorus content as they are applied: 0.05 to 0.08 mg/l of total phosphorus, 0.015 to 0.05 mg/l of dissolved phosphorus.
- There is a progressive decline through the year in concentrations, with the decline more pronounced with dissolved phosphorus than total phosphorus. (Turbidity associated with relatively high June flows and release of decomposition products during the storage period might be expected to cause the high initial values. Displacement of waters stored at American Falls by "cleaner" waters from upstream reservoirs might be expected to result in the lower concentrations, as should biotic uptake in the summer with its higher temperatures and greater hours of sunlight.)
- Flow reduction is immediate and severe: In June, 80 percent of irrigation water applied is not matched by return flows; in July, the ratio of returned to applied water is 1 to 4, in August 1 to 7. Even in October, with irrigation almost ended, return flows are less than 60 percent of irrigation diversions.
- Concentrations of total phosphorus in irrigation return waters are two to three times those of applied waters; concentrations of dissolved phosphorus are two to 10 times as great. Quite clearly, the filtering action of soils either does not occur or is offset by other forces.

Conjectures have been advanced for the high levels of phosphorus in return water, but none explain the entire phenomenon. One explanation might be that several of the return drains receive municipal sewage, and in December

TABLE IX-10

PHOSPHORUS BALANCE IN SOUTHEASTERN IDAHO (BURLEY-MINIDOKA IRRIGATION AREA)

	June	July	August (1972)	October	December
Mean phosphorus concentrations (mg/l)					
Total phosphorus					
Applied water	.08	.06	.05	.05	–
Drain water	.17	.17	.16	.17	.40
Dissolved phosphorus					
Applied water	.05	.03	.025	.015	–
Drain water	.11	.13	.13	.11	.17
Flow (cfs)					
Irrigation input	1,445	1,400	1,400	450	0
Drain output	302	323	208	257	99
Net stream impact	-1,143	-1,077	-1,192	-193	+99
Phosphorus balance (lb./day)					
Total phosphorus					
Irrigation input	623	453	377	121	–
Drain output	277	296	179	235	213
Net stream loading	-346	-157	-198	+114	+213
Dissolved phosphorus					
Irrigation input	389	226	189	36	–
Drain output	179	226	146	152	91
Net stream loading	210	–	-43	+116	+91

a sugar refinery is discharging to one of them. These sources might account for a good part of the total phosphorus observed, but scarcely for the high dissolved phosphorus level. A second explanation might be fallout of particulate phosphate from the phosphate factories 60 to 100 miles away from sampling areas; a third might be the dissolved phosphorus in animal waters on areas receiving irrigation water.

At any rate, the surprising data with respect to phosphorus in irrigation return waters offer a useful insight into algae production mechanics, even though the question of the source of the phosphorus cannot be answered. The warm, sluggish irrigation return drains, rich in nitrogen and phosphorus, may well serve as algae incubators, much as reservoirs do. So the biotic material nurtured in drains could pass into the Snake and be recycled repeatedly until it is intercepted by some reservoir.

Salinity, Acidity, and Alkalinity

Dissolved solids concentrations in the Snake River basin range from less than 20 to greater than 2,000 mg/l (Figure IX-9). Headwaters of the Snake and its tributaries are dilute, seldom exceeding 150 mg/l. Below the confluence of the Snake with the Henrys Fork, and in the lower reaches of tributaries, concentrations rise. In the semiarid Snake Plain—where widespread irrigation results in extensive leaching, even as it depresses flows—dissolved solids concentrations progressively build up, peaking just above the Thousand Springs. In the central basin, the average dissolved solids concentrations in surface water run about 300 mg/l, and intensively utilized irrigation streams, such as the Malheur and Owyhee Rivers, may exceed the average several times over. In the lower basin, and in the waters of the Payette and Weiser Rivers of the central basin, chemical quality is generally higher than in upstream areas below the Henrys Fork.

Organic materials constitute a significant portion of total dissolved solid materials found in waters of the upper and central basins. During summer, when the largest portion of the total movement of the materials mass occurs, organics constitute 25 to 30 percent of the matter in solution. In winter, with lower flows and lower leaching rates, organics probably continue to account for a significant portion of dissolved solids concentrations, wastes from food processing supplanting aquatic vegetation as the source.

Typical of arid area streams, the Snake River is quite alkaline over much of its area of passage (Figure IX-10). Idaho's water quality criteria reflect that natural alkalinity by setting the upper limit for pH at 9.0 standard units from the river mouth to the confluence with the Grande Ronde.

Waste discharges have a definite impact on pH levels at one point at least on the stream. At Lewiston, acidic discharges of Potlatch Forest (pulp and paper plants and lumber and plywood mills) drive pH below the neutral point. It is possible, too, that caustic potato peel wastes reinforce the natural alkalinity of the upper and middle rivers during the food-processing season.

Oxygen Depletion

For the most part the Snake River exceeds its minimum dissolved oxygen criterion from headwaters to mouth. Concentrations are typically very close to saturation, with temperature and barometric pressure apparently having more influence than waste discharges (Figure IX-11).

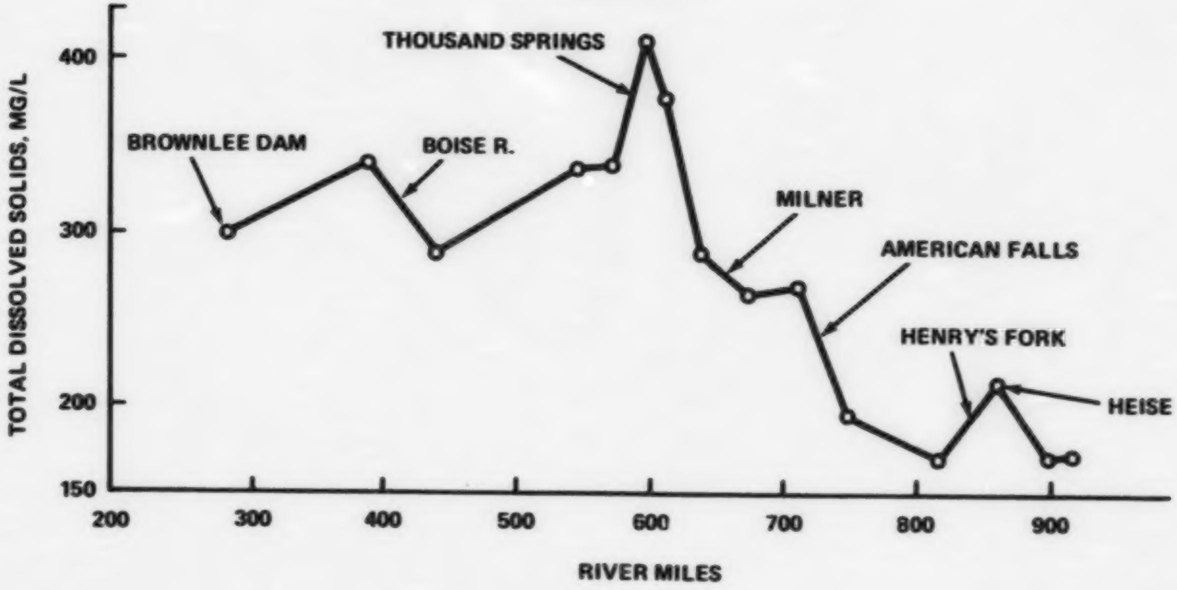
Significant reductions occur in the level of dissolved oxygen in the reservoir sequence of the upper river (behind American Falls, Minidoka, and Milner Dams), with the entry of the Thousand Springs, in Brownlee and Oxbow reservoirs, and below Lewiston, Idaho/Clarkston, Wash. These depressions, with the exception of that in the Thousand Springs area, are all associated with industrial and municipal waste discharges, although the principal influence is recognized to be the reservoir environment itself rather than volume of waste discharge. Expansion of waste treatment over the past decade has materially reduced the magnitude of several of the depressions, none of which is at this time pronounced enough to indicate a serious threat to legal water quality criteria. (The data upon which Figure IX-11 are based do not reflect subsequent expansion of municipal and industrial waste treatment in the Lewiston/Clarkston area.)

Figure IX-9 **RIVER PROFILE**

SNAKE RIVER

TOTAL DISSOLVED SOLIDS

OCTOBER 1965



SOURCE: CHEMICAL QUALITY INVESTIGATIONS OF SURFACE WATER IN IDAHO, 1965-66
U.S.G.S., IDAHO DEPT. OF RECLAMATION

Figure IX-10 **RIVER PROFILE**

SNAKE RIVER

pH

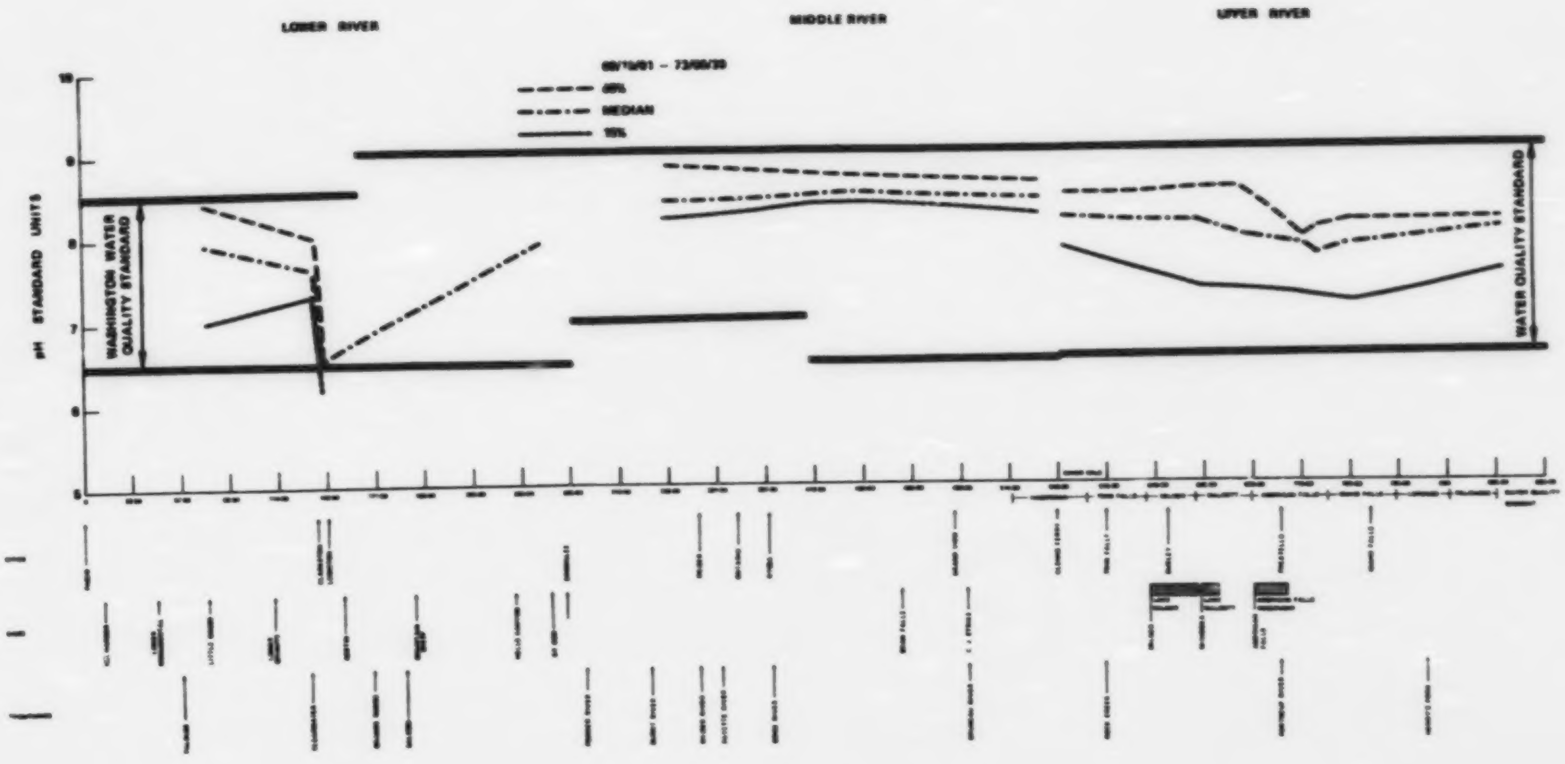
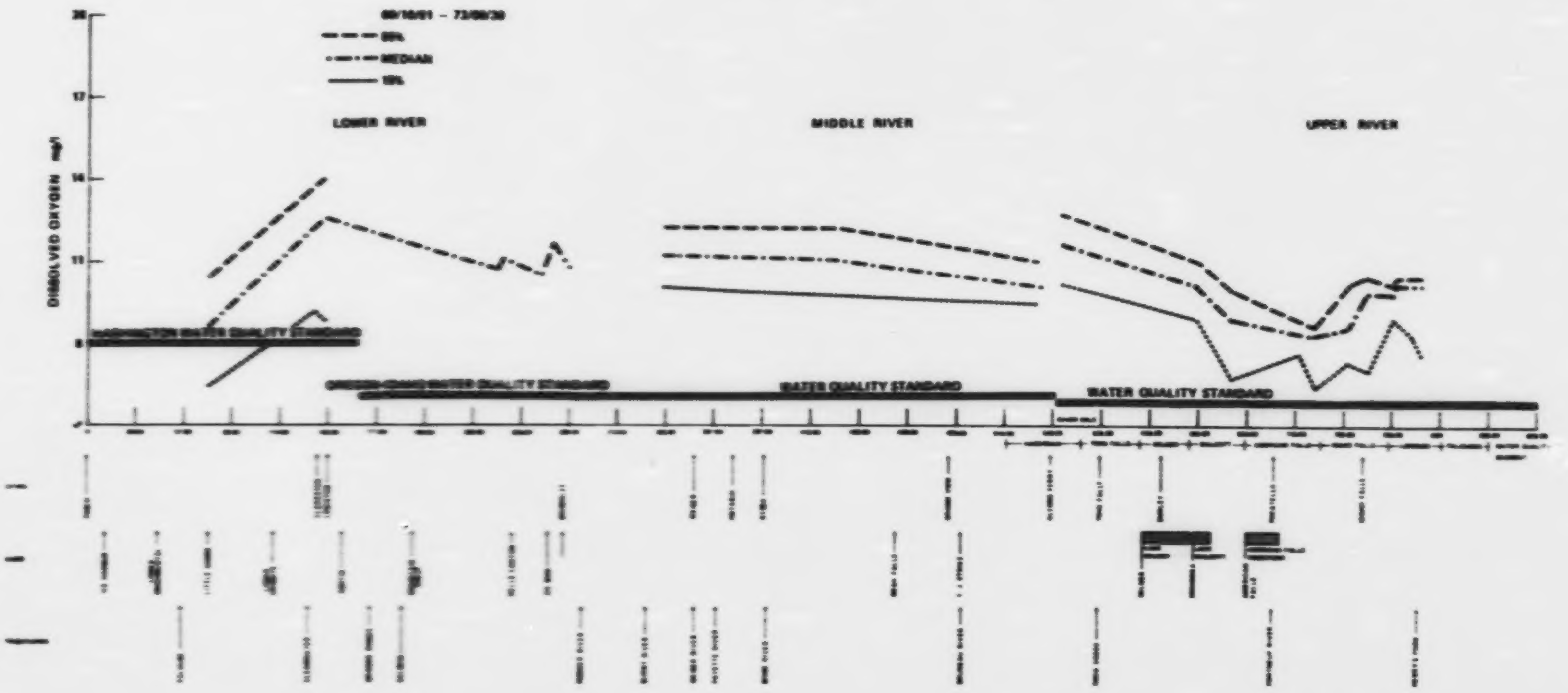


Figure IX-11 **RIVER PROFILE**

SNAKE RIVER

DISSOLVED OXYGEN



But the apparent adherence to water quality criteria does not adequately reflect the dissolved oxygen conditions of the Snake. Broad diurnal fluctuations caused by plant respiration are thought to be hostile to many fish species. Variation in dissolved oxygen concentrations can be as damaging to the salmonids, in particular, as an inadequate supply. In early fall, when temperature and light penetration are still sufficient to produce abundant plant growths, but hours of darkness have begun to exceed hours of sunlight, the impact of diurnal variation may be particularly pronounced. At that time the daily period of oxygen supersaturation must be quite limited, and pre-dawn concentrations may be insufficient to meet the oxygen requirements of fish.

Not only time, but depth as well affects oxygen availability. The lower waters of every reservoir may be assumed to be deficient in oxygen (Figure IX-12). Zero concentrations have been recorded in the lower waters of Brownlee Reservoir and probably occur quite often in the majority of the Snake's reservoirs. The condition is probably most damaging in winter in the upper river, when ice cover precludes reaeration, and decay of accumulated organics draws over an extended period upon the relatively static oxygen resources of reservoirs.

Streamflow and temperature are the prime influences on dissolved oxygen levels of the Snake. At this time, seasonal lows tend to occur in July and August (Figure IX-13). They are, then, independent of waste discharges, which peak in winter over much of the river. No trend, other than seasonal flow and temperature correlations, can be developed for the past 4 or 5 years. Today's conditions, however, are much superior to those of a decade ago, when winter oxygen depressions caused by discharge of food-processing wastes were the norm in Brownlee Reservoir, especially in Milner Reservoir, and also in the Boise River, a tributary of the Snake (Figure IX-14).

Health Hazards and Aesthetic Degradation

All of the States through which the Snake River flows require that total coliforms meet a standard, with 1,000 organisms per 100 ml the acceptable upper limit for most of the stream. That standard is not often met in free-flowing portions of the stream. Values run from 100 to 10,000 organisms per 100 ml through most of the river at all times of year, and values above 5,000 predominate immediately below each of the population centers of the upper river, as well as in the reach between the mouth of the Boise River and Brownlee Pool (Figure IX-15).

Waste discharges—particularly the winter discharges of potato processors—appear to be substantial sources of bacteria (Table IX-11). Significantly, winter coliform counts are substantially unchanged from those of summer except in the immediate area of processors' discharges. The logical conclusion is that warm, nutrient-rich processing wastes provide an immediate stimulus to bacterial populations, but that die-off occurs rapidly in the natural environment of the stream.

Runoff is a more pervasive influence on bacterial counts. Populations increase six- to ten-fold immediately after a rain and experience a subsequent regrowth to 1.5 to 2 times equilibrium levels in the first few days after the flush and subsequent die-off. Intensity of land use appears to be a definite factor in bacterial response to runoff. Stream reaches downstream of human and cattle concentrations tend to display higher bacterial populations both before and after a runoff event than do less densely used areas (Figure IX-16).

There is no evidence of a seasonal trend, in spite of enormous winter bacteria discharge with industrial wastes. Neither does there appear to be any discernible long term trend. Bacterial populations in 1962-66, under a considerably lower aggregate level of waste treatment, were substantially the same in location and concentration as those of the past 4 years (Figure IX-17).

PROJECTION

The circumstances that affect Snake River water quality are diverse, scattered, and linked to fundamental alterations of hydrology. Thus, it is not possible at this time to determine the precise effects of new controls such as additional waste treatment measures or new controls on feedlot operators and irrigators. However, even if waste

TABLE IX-11

SNAKE RIVER: TOTAL COLIFORM CONCENTRATIONS OF MAJOR WASTE DISCHARGES ON UPPER RIVER (1971-73)

Source	Total coliforms (no./100 ml)	
	Summer	Winter
Idaho Falls Sewage Plant	3,900	4,000
Shelley Sewage Plant	3,300	NA
Blackfoot Sewage Plant	344,000	37,000,000
Rupert Sewage Plant	40	200,000
Gold Valley Packing Co.	6,500	200,000
Idaho Potato Foods	–	8,000,000
Western Farmers	–	2,600,000
Rogers Brothers	–	172,000,000
Idaho Potato Starch	–	23,000,000
American Potato Co.	–	220,000,000
J. R. Simplot Co.	–	43,000,000
Ore-Ida Foods	–	25,000,000

loads increase because of growth or relaxation of controls, it is most unlikely that the Snake could return to the unfortunate conditions that prevailed in the early 1960's; so, at least in the short term, severe degradation seems most unlikely.

There are strong indications that water quality conditions are presently very near the optimum level, given existing development and technology. Mathematical simulation of stream conditions indicates that total elimination of phosphorus discharged from point sources could not bring the level of the critical nutrient below the nuisance algae potentiating level. Temperature conditions are the result of nature and the system of reservoirs. Reduction of dissolved gas supersaturation is subject to technological uncertainty and significant institutional constraints. There are strong reasons to believe that bacteria levels are largely a function of runoff. There appears to be no means of reversing the materials-accumulating processes of reservoirs.

Tight maintenance of controls will apparently be necessary to sustain the existing quality of the free-flowing portions of the Snake, and gradual eutrophication of reservoirs is inescapable, although with more knowledge, a way may be found to retard the process.

The initial phase of EPA's Region X's monitoring program has been conducted in the upper Snake River basin, and both the central and lower basins are scheduled for study in 1975.

Figure IX-12 DEPTH ANALYSIS

SNAKE RIVER

DISSOLVED OXYGEN

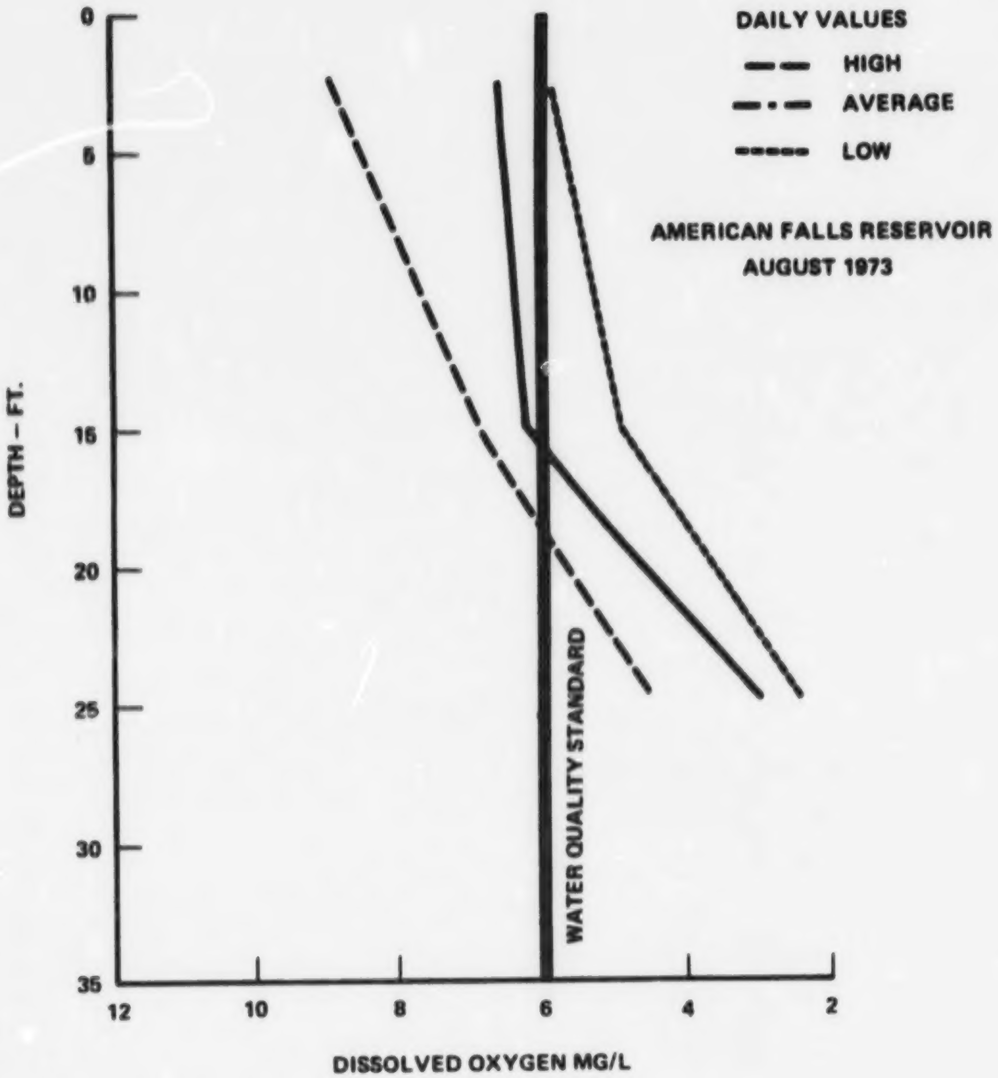


Figure IX-13 **TIME TRENDS AT RIVER MILEPOINTS**

SNAKE RIVER

DISSOLVED OXYGEN

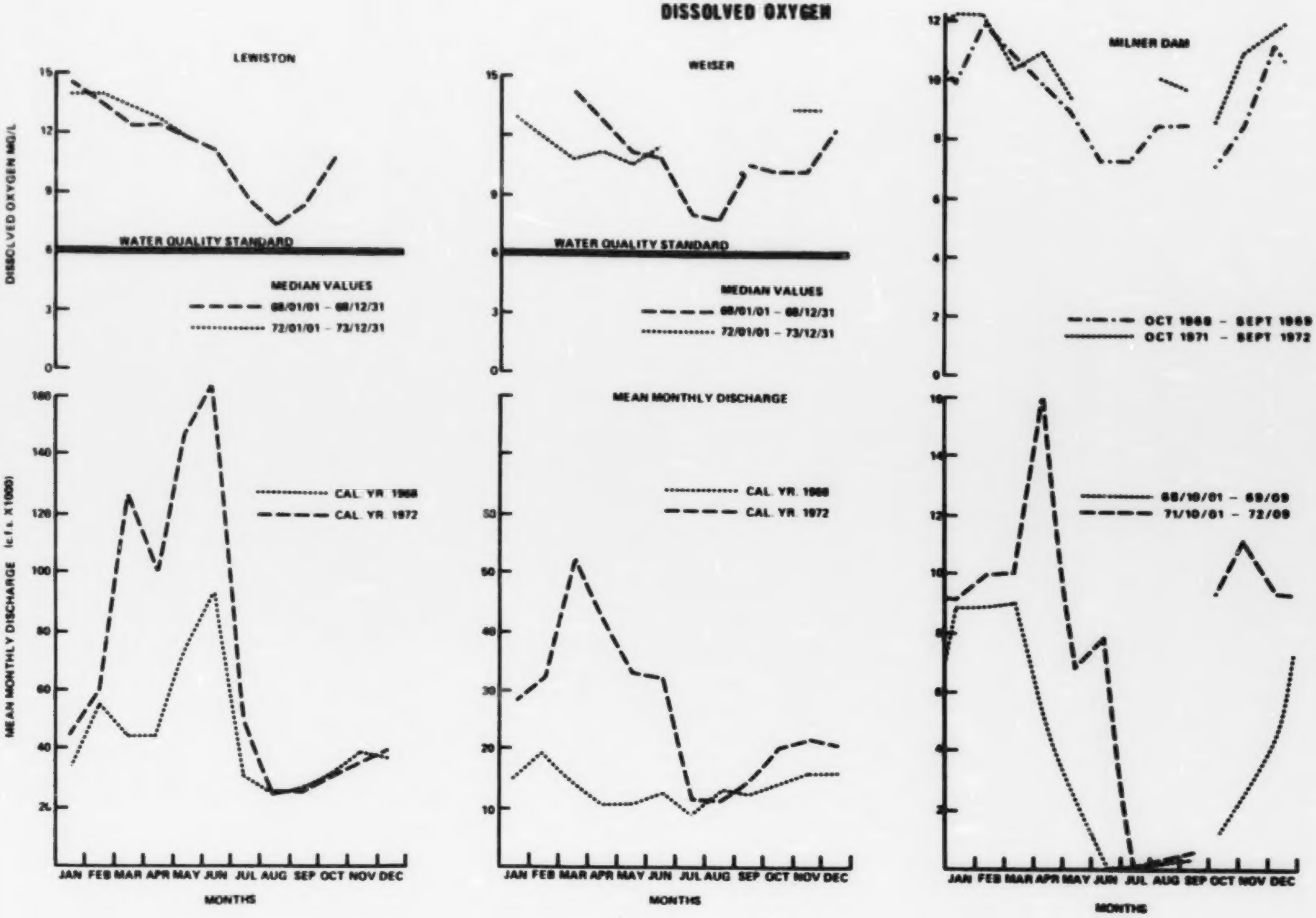


Figure IX-14 **RIVER PROFILE**
SNAKE RIVER
DISSOLVED OXYGEN
1962-1966 DETERMINATIONS

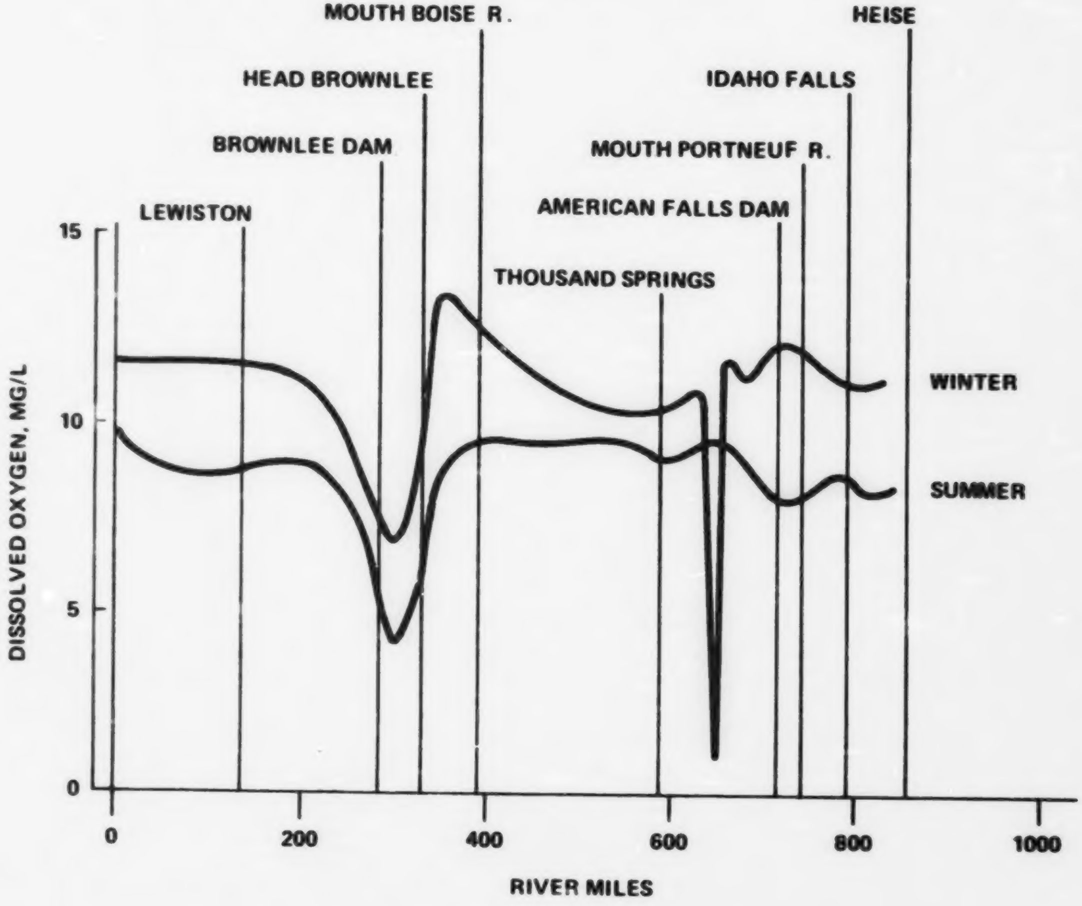


Figure IX-15 **RIVER PROFILE**

SNAKE RIVER

TOTAL COLIFORMS

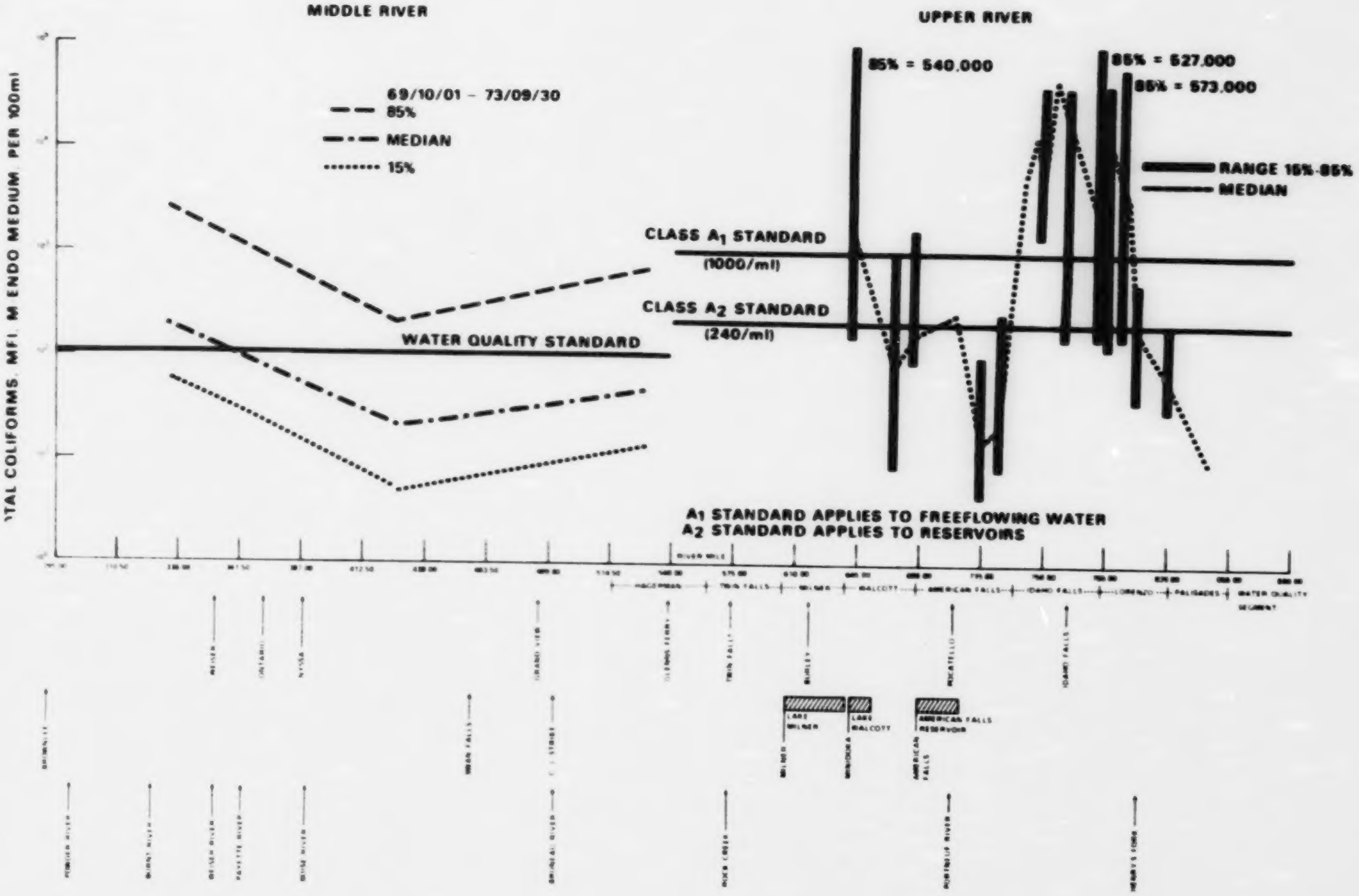


Figure IX-16

TIME TRENDS AFTER RAINFALL

SNAKE RIVER

COLIFORM BACTERIA

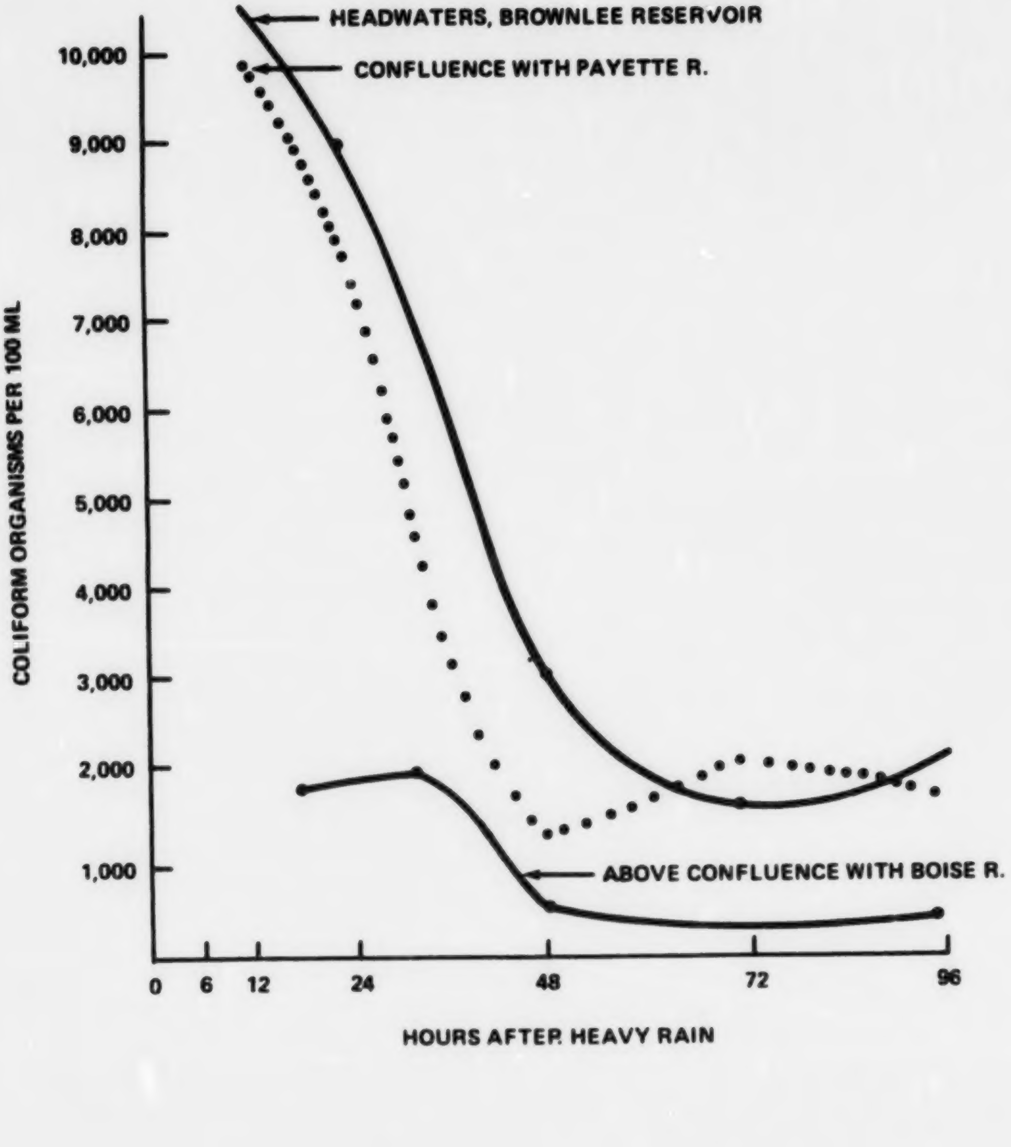
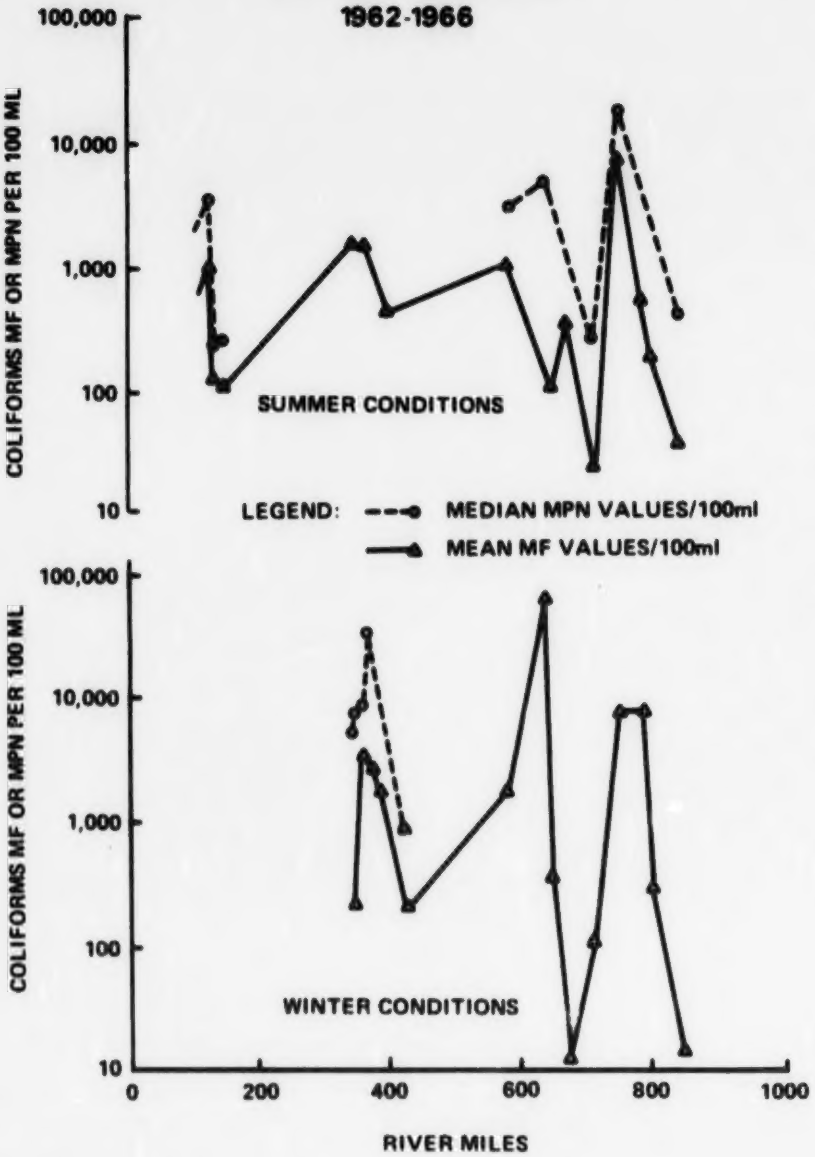


Figure IX-17 SEASONAL RIVER PROFILES

SNAKE RIVER

COLIFORM BACTERIA

1962-1966



X. WILLAMETTE RIVER

The quality of the Willamette River has improved dramatically over the past 10 years. Dissolved oxygen no longer violates standards, as it frequently did in the past during periods of low flow. The total coliform standard continues to be exceeded more often than met, especially at high stream flows, but 1971-72 counts are distinctly lower than 1966-67 counts. Sulfite waste liquor, which is toxic to fish, is still high in the lower 80 miles of the river, even after a twofold improvement in 1971-72 over 1966-67. Violations of the pH criteria decreased noticeably over the past 10 years.

The key pollutants show the following trends:

- *Harmful Substances.* Sulfite waste liquor from pulp and paper wastes introduces substantial amounts of wood phenols, which are represented by the Pearl Benson Index (PBI) number. The upper river has very low (less than 5 mg/l) PBI values, but in the lower 80 miles the values are quite high (30 to 40 mg/l). The 1966-67 levels were generally twice those of 1971-72 at all points below Salem.

- *Physical Modification.* During high stream flows the river is very turbid, carrying large amounts of sediment. Man's activities (logging, construction, agriculture) are primarily responsible. Temperature criteria are exceeded repeatedly in the summer from a combination of climate and hydrology.

- *Eutrophication Potential.* Excessive growths of algae have not been reported even though available nitrogen and phosphorus exceed reference levels. Nutrients are higher during low flow than high flow, suggesting point source influence. Some tributaries have natural sources such as runoff and inputs from reservoir turnovers.

- *Salinity, Acidity, and Alkalinity.* The waters of the Willamette are low in dissolved mineral salts, with dissolved solids concentration averaging about 60 mg/l. Violations of the pH criteria have been observed, but the steady decrease in violations over the past 10 years indicates improved industrial treatment of acid wastes.

- *Oxygen Depletion.* Dissolved oxygen levels throughout the river have improved over the past 5 years. Standards are being met during high flow and even at extreme low flow. This was of particular significance in 1973 when the Pacific Northwest experienced its major drought of record with no violations. Dissolved oxygen improvements stem from continued decreases in BOD_5 discharges and streamflow augmentation by storage reservoirs.

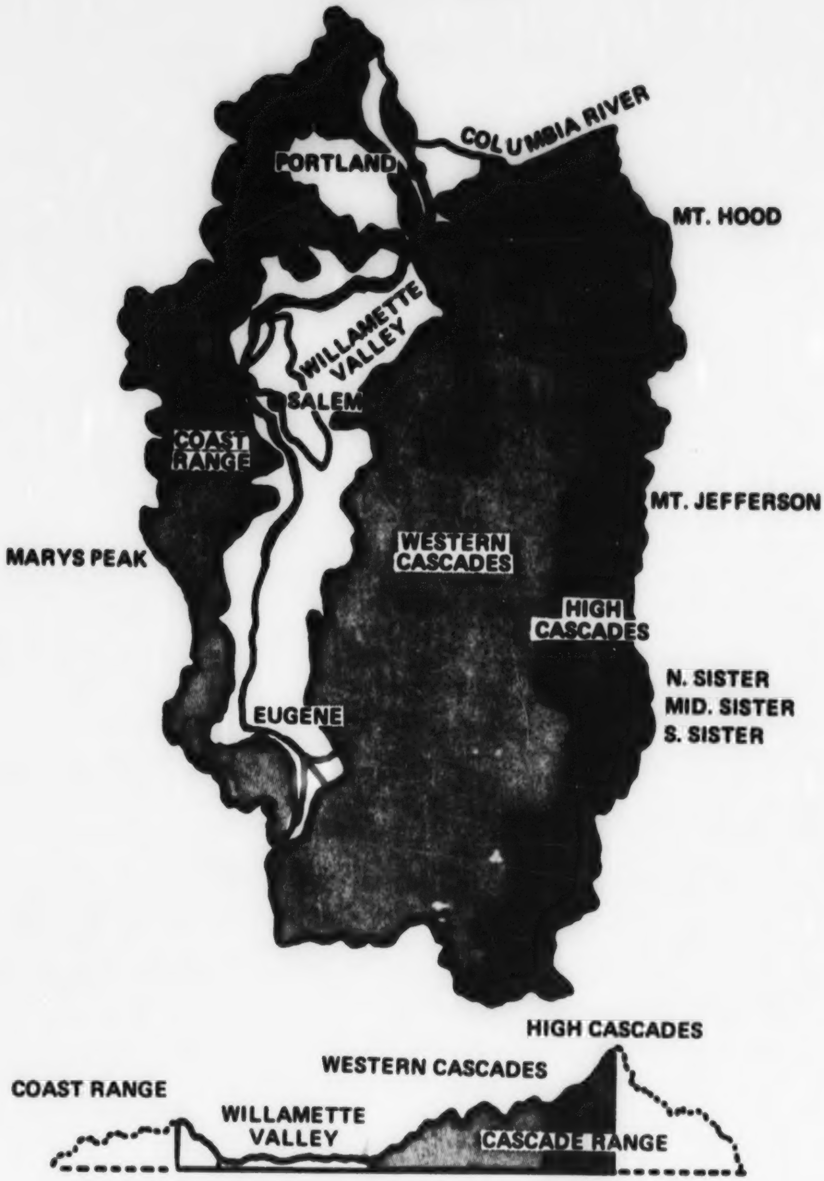
- *Health Hazards and Aesthetic Degradation.* Bacterial quality (total coliform counts) is improving but still exceeds standards. Total and fecal coliform counts are generally higher during high stream flows, suggesting the sources to be combined sewers and farm runoff. Counts may also climb during seasons when disinfection for protection of swimmers and boaters has been reduced.

GENERAL PHYSICAL DESCRIPTION

The Willamette River is one of four major tributaries (the others being the Snake, Kootenai, and Clark Fork Rivers) that supply, in roughly equal parts, something over half of the total flow of the Columbia River. The Willamette drains just over 12,000 square miles of northwest Oregon, meanders 188 miles from the confluence of the Middle Fork and North Fork that creates the river, and develops an average annual flow of 38,500 cfs (Figure X-1).

FIGURE X-1. BASIN MAP

WILLAMETTE RIVER



COLUMBIA RIVER
PORTLAND
MT. HOOD
WILLAMETTE VALLEY
SALEM
COAST RANGE
MT. JEFFERSON
MARYS PEAK
WESTERN CASCADES
HIGH CASCADES
N. SISTER
MID. SISTER
S. SISTER
EUGENE
HIGH CASCADES
WESTERN CASCADES
COAST RANGE
WILLAMETTE VALLEY
CASCADE RANGE

SOURCE: PACIFIC NORTHWEST RIVER BASINS COMMISSION

Natural streamflow is highly variable, a result of a precipitation pattern that typically ranges from more than 5 to almost 8 inches per month from November to February, down to under 1/2 an inch in July and August. (From June to September the Willamette Valley is more arid than west Texas.) Streamflow at Salem, Oreg., has ranged from a fairly routine summer volume of less than 2,500 cfs, to an estimated 500,000 cfs during the largest flood of record in December 1861 (Figure X-2). Construction on virtually every tributary of 19 storage reservoirs for flood control, hydroelectric power production, and navigation has evened out the extremes of flow; the system is currently managed to attempt to maintain a minimum flow of 6,000 cfs at Salem.

The watershed is densely populated and highly industrialized. More than 1.5 million persons—70 percent of Oregon's population—live in the Willamette River basin. Some 800,000 people are in the Oregon portion of the Portland metropolitan area, about 65,000 live in Salem, and 100,000 in Eugene and Springfield.

Because most of the basin is mountainous and forested, settlements are concentrated on the narrow valley floor. Lumbering and farming are the foundations of the economic base, but a diverse manufacturing industry and flourishing services have relegated lumbering and farming to something under 15 percent of labor force employment.

POLLUTION PROBLEMS AND SOURCES

The Willamette has been the chronically polluted river of the West. The Willamette Valley was the original focus of settlement on the Pacific Coast; its population density has consistently been higher than other Western areas, and for most of the past 50 years the Willamette with its low summer flow has proved inadequate to assimilate the wastes produced by that concentration of people.

At the root of the problem is the topography of the basin. At about RM 50, the Willamette enters a natural depression, the Newberg Pool, in which stream velocity drops markedly. The result is a reduced rate of reoxygenation and accumulation of settleable organic material; those factors in turn cause dissolved oxygen concentrations to decline. Willamette Falls (RM 26) provides some reaeration, but for many years a substantial portion of summer flow has not aerated since it has been diverted through a power plant. Below the Falls, the broadened Willamette forms Portland Harbor, another slack water area where tidal forces and the mighty flows of the Columbia—as much as 40 times the volume of the Willamette in late summer—act to retard the Willamette's flow at precisely the point that it contains its greatest waste loadings.

The principal source of wastes on the Willamette is the production of wood pulp and paper. Oregon's first paper mill was installed at Willamette Falls in 1889. Later in the same year another mill was built at Lebanon on a tributary of the Willamette. Construction of a second pulp mill Willamette Falls in 1908, a mill at Salem in 1920, and a mill at Newberg in 1927 condemned the lower Willamette River to years of continuous summer pollution.

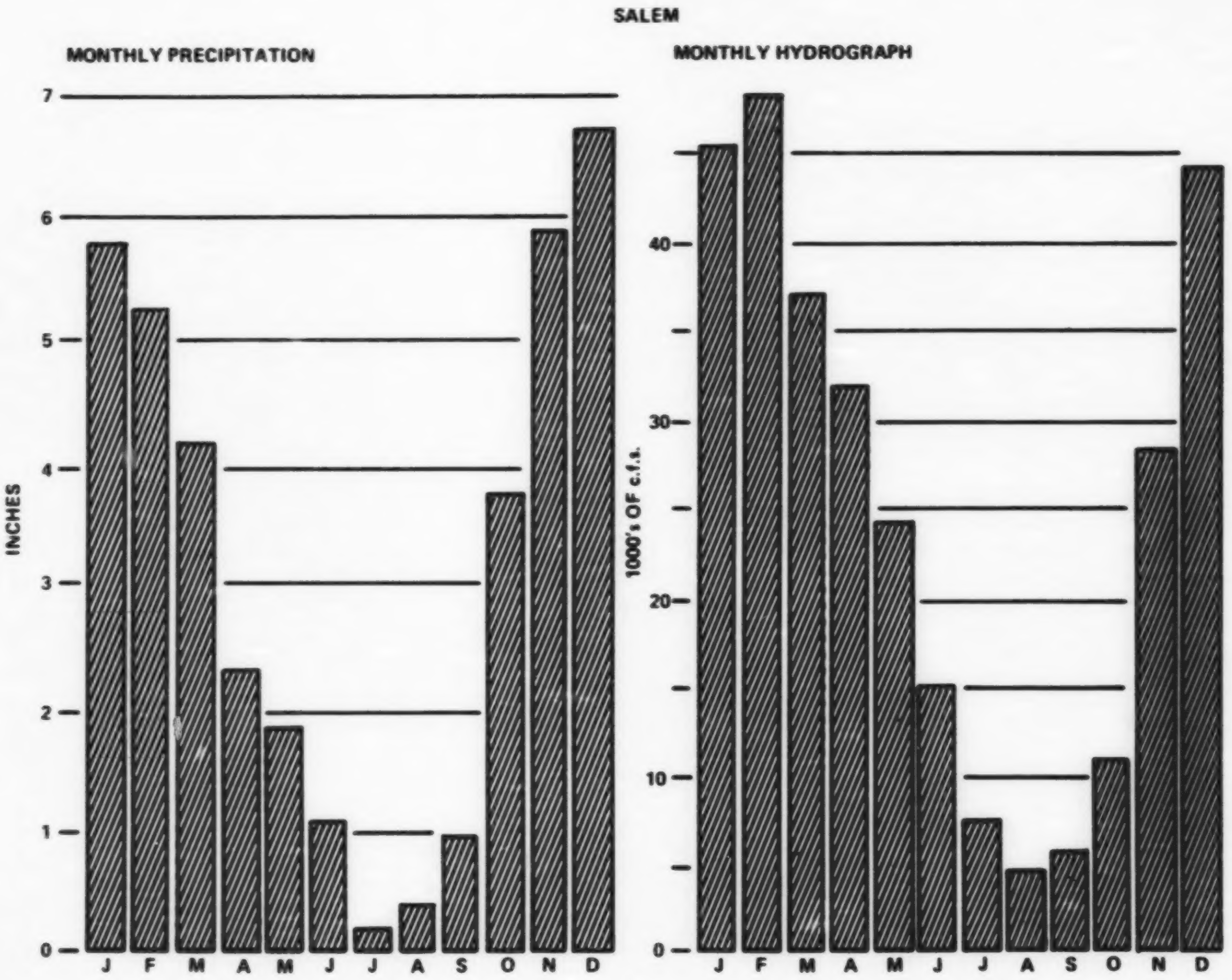
The symptoms of pollution were classic: low dissolved oxygen, high bacterial counts, floating and suspended solids. Portland Harbor became impassable in summer for migrating salmon, and ultimately uninhabitable by carp. On warm summer days the river stank. By 1926, the Oregon State Board of Health organized an Anti-Pollution League. The pollution of the Willamette was an issue in the 1928 election (as in a majority of the 19 subsequent elections), and in 1935 a State water pollution control law was passed, largely as a reaction against the pollution of the Willamette River.

From that time forward a continuous campaign was mounted to clean up the river. Still, the Willamette remained polluted for years, but slowly, beginning with small communities, discharges were cleaned up. Between 1917 and 1929, only three sewage treatment plants were installed in the Willamette basin. From 1929 until the end of the war, eight were built, followed by 15 in the immediate postwar years 1946 to 1951. At the same time, the first really significant step in the ultimate cleanup of the Willamette was taken when the City of Portland built a treatment plant discharging to the Columbia River and began to intercept its various outfalls, ultimately taking the wastes of 400,000 people out of the Willamette entirely.

FIGURE X-2. TIME TRENDS AT RIVER MILEPOINTS

WILLAMETTE RIVER

PRECIPITATION AND FLOW



SOURCE: PACIFIC NORTHWEST RIVER BASINS COMMISSION

New pulp mills that went into operation at Springfield and Albany after World War II used the sulfate process, in which chemical recovery reduces 90 percent or more of the strength of waste discharges. In the middle of the 1950's, the Oregon State Sanitary Authority pressed existing pulp mills to reduce waste discharges. At first this was achieved by storing wastes during periods of low flow for later release as flows increased. During the 1960's, waste treatment and process modifications came to be required of the mills. Also in the 1960's, cities along the river began to upgrade existing waste treatment plants, to provide secondary treatment, and also to increase treatment capacity in cases where growth had outstripped original specifications. Food processors and miscellaneous industries progressively stopped discharging to the river and began to discharge to public sewer systems.

Between 1952 and 1957, summertime BOD_5 discharged to the Willamette was halved (Figure X-3). It was halved again between 1957 and 1967, and a third time between 1967 and 1972. In addition, waste was controlled year-round, not just seasonally.

Equally significant, the system of dams and reservoirs that the U.S. Army Corps of Engineers installed on the various tributaries of the Willamette sharply increased summer flows. The winter floods that were stored to produce electricity and sustain navigation doubled the August-September flow of the Willamette. From the natural annual low of 2,500-3,500 cfs, flows at Salem rose to 5,000 cfs or greater and have been maintained at such levels for over a decade.

The result has been an enormous improvement in the quality of the Willamette (Table X-1). Bacterial counts are orders of magnitude below their earlier peaks, and the dissolved oxygen depression of the lower river has been almost eliminated (Figure X-4).

Nonpoint Sources

Unlike the usual pattern for Pacific Northwest waters, nonpoint influences have not played a significant part in pollution of the Willamette River. Temperature and streamflow are, of course, the overriding determinants of stream quality. Temperature is slightly affected by human actions, however, and streamflow regulation is generally a positive influence on the quality of the Willamette.

TABLE X-1

WILLAMETTE RIVER: TRENDS IN DISSOLVED OXYGEN
AND COLIFORM COUNTS*

<table>
<tr><th rowspan="2">Location (river miles from mouth)</th><th colspan="4">Dissolved oxygen (% saturation)</th></tr>
<tr><th>1950</th><th>1957</th><th>1961</th><th>1972</th></tr>
<tr><td>Salem (84)</td><td>85</td><td>90</td><td>90</td><td>85</td></tr>
<tr><td>Newberg (50)</td><td>70</td><td>75</td><td>85</td><td>85</td></tr>
<tr><td>Oswego (21)</td><td>45</td><td>30</td><td>65</td><td>90</td></tr>
<tr><td>Swan Island (5)</td><td>20</td><td>25</td><td>40</td><td>80</td></tr>
<tr><td></td><td colspan="4">Total coliforms (no./100 ml)*</td></tr>
<tr><td></td><td>1929</td><td colspan="2">1962</td><td>1972</td></tr>
<tr><td>Salem</td><td>300,000</td><td colspan="2">33,000</td><td>8,000</td></tr>
<tr><td>Newberg</td><td>1,000,000</td><td colspan="2">11,000</td><td>3,000</td></tr>
<tr><td>Oswego</td><td>500,000</td><td colspan="2">9,000</td><td>500</td></tr>
<tr><td>Swan Island</td><td>600,000</td><td colspan="2">1,800</td><td>700</td></tr>
</table>

*Data may not be statistically comparable, given differences in sampling and laboratory procedures.

Figure X-3. TIME TREND
WILLAMETTE RIVER
BIOCHEMICAL OXYGEN DEMAND

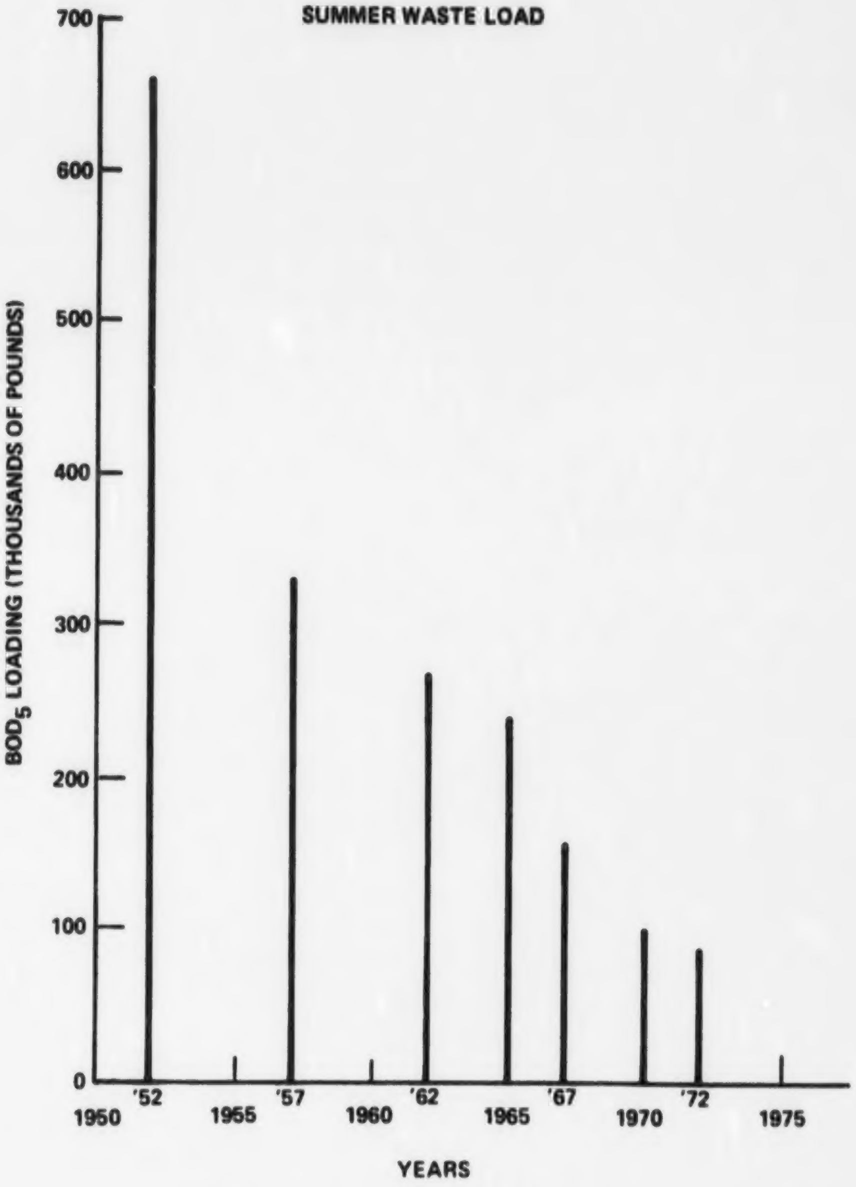
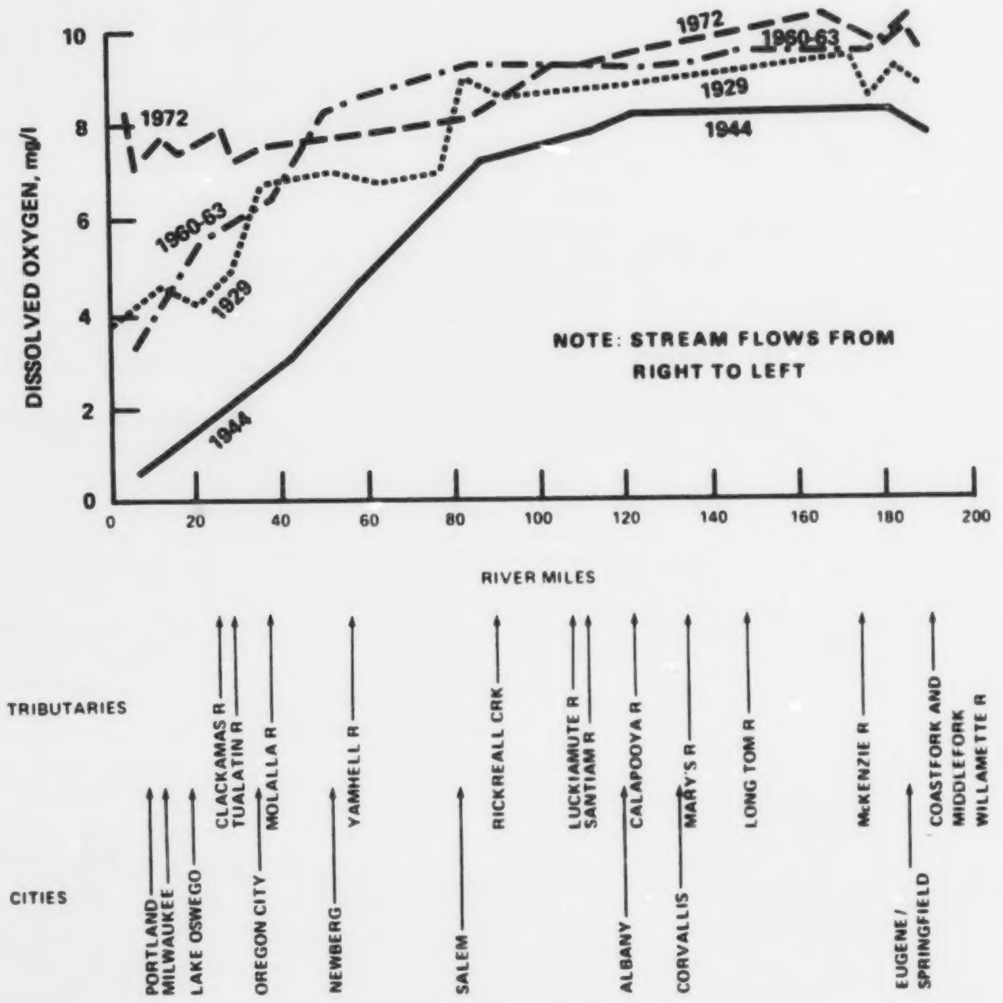


Figure X-4 RIVER PROFILE
WILLAMETTE RIVER
SUMMER DISSOLVED OXYGEN



Turbidity and excess sediments are invariably associated with winter flooding. Soil displacement caused by logging and construction contribute to the condition. Both logging and construction practices have improved significantly over the past 25 to 30 years, although there is probably room for additional improvement.

Close to half a million acres are irrigated in the watershed, with withdrawals for the purpose averaging about 2.3 feet of water per acre per season. (The value refers only to agricultural irrigation and does not include very extensive urban and suburban lawn watering, which involves much less acreage and much heavier applications per acre.) Irrigation is almost exclusively by sprinkler and involves practically no surface runoff. Hence there is no detectable impact on turbidity, temperature, or transport of suspended and dissolved materials having toxic or oxygen-demanding characteristics. Soils of the very humid valley have been thoroughly leached, so there is no detectable pickup of dissolved mineral solids from subsurface irrigation return flows, and the concentrating effects of evapotranspiration are not detectable, given the seasonal pattern of surface and subsurface flows. (Irrigation does cause a significant deterioration of the quality of tributaries entering the Willamette from the west, in that the small sluggish streams that rise in the Coast Range are severely depleted by withdrawals. Some of the lesser streams are dried up each summer, and increased temperature and reduced assimilative capacity are direct consequences of flow reduction in every case.)

A quarter of a million farm animals—mostly dairy and breeding stock on the valuable Willamette Valley lands—are found in the basin. Localized bacteria-promoting effects are suspected but have never been documented.

The highly urbanized Willamette Valley contains a significant amount of paved and otherwise altered landforms susceptible to rapid runoff and transmission of contaminants by rainwater. These potentially polluting mechanics are worsened by combined storm and sanitary sewers in the older sewer systems. The effects are mediated, however, by the precipitation pattern, since the almost continuous gentle rains of the area do not allow contaminants to build up as they do in other areas with equal, but intermittent, precipitation.

Navigation is a minor source of pollution, particularly in Portland Harbor, one of the world's busiest freshwater ports. Though sanitary controls are enforced by the Coast Guard, Port of Portland, and other authorities, small spills still occur intermittently. Floating solids and wood sugars from log rafting and water storage persist, although stringent regulations are gradually forcing the wood products industries to move to truck hauling and dryland storage.

Gravel dredging in the river and off-river gravel washing continue to contribute to sediments and turbidity, but they are much reduced. Navigational dredging is almost continuous in Portland Harbor, or in Multnomah Channel below the harbor, and is another source of localized turbidity.

Bottom deposits in Portland Harbor are a significant, but diminishing, influence on the quality of the lower reach of the river. Prior to the current intensive waste regulation of the Willamette, the bottom of the deep, sluggish harbor was annually blanketed with settled wood fibers from upstream pulp mills and planktonic growths stimulated by pulp mill and municipal discharges. Each year these were partially scoured by winter flooding, then built up again over the course of the year. Their decay exerted a continuing demand on available dissolved oxygen; concurrent anaerobic decomposition going on within the sludge mantle produced gas whose buoyant effect on the deposits caused the frequent upwelling of odorous, unsightly sludge mats.

Installation of primary waste treatment and consequent elimination of the bulk of pulp mill wood fibers, together with natural scouring, was expected to eliminate the problem. Instead, they changed its nature. While fibrous sediments were largely eliminated, the residual BOD_5 of treated pulp mill discharges continued to promote biotic—principally bacterial—activity. Settled biomass (sludge) continued to blanket the bottom with a fine sludge suspension, making the deepest section of the water column a highly active environment very similar to the mixed liquor of a secondary sewage treatment plant. BOD_5 from the accumulated sludge was calculated to be in the range of 30,000 to 35,000 pounds a day as recently as 1969, resulting in an estimated 0.5 to 0.8 mg/l reduction of dissolved oxygen in Portland Harbor. More intensive waste treatment installed since 1969 appears to have largely eliminated this problem. Bottom sampling conducted by the U.S. Geological Survey in 1973 found virtually no trace of the sludge beds which in 1969 were known to blanket over 1 million square meters of Portland Harbor bottom.

Point Sources

The Willamette River has provided a classic case of water pollution, in that the pollution could be attributed clearly and unequivocally to waste discharges. Reduction of the strength of the discharges by treatment and industrial process modification relieved the pollution.

Although total waste discharge, measured as BOD_5, has been reduced to a tenth of its level of the early 1950's, the Willamette continues to receive a significant daily waste load–more than 85,000 pounds of BOD_5 per day. (A third as much more is probably carried to the river partially assimilated as the result of discharge to tributaries, notably from suburbs of Portland that discharge to the Tualatin River and from pulp mills that discharge to the McKenzie and South Santiam Rivers.)

The number of significant, identified dischargers is small (Table X-2). Fifteen municipal sewage treatment plants discharge 57.3 million gallons a day; six pulp or paper mills discharge 48.6 million gallons a day; two forest products plants discharge 0.1 million gallons a day; three other factories discharge 36.6 million gallons a day. All provide a high degree of waste treatment or control. The State of Oregon requires that discharges to the Willamette contain no more than 20 mg/l of BOD_5 and suspended solids–a requirement that is 50 percent more stringent than Federal effluent limits. (Discharges to some tributaries are required to be controlled to 10 and 5 mg/l.)

The small number of dischargers in so densely populated an area is, in some measure, due to the fact that there are a number of tributaries that provide a more convenient discharge point for some communities and industries; but it is also an expression of policy. With expansion of waste treatment, discharges have been consolidated. Portland operates three waste treatment plants. Only one of these, Tryon Creek, discharges to the Willamette; most of the loading to that plant comes from suburban communities outside and upstream of the Portland city limits. Salem's plant also receives a significant external load; on a seasonal basis, 80 percent of the Salem load is derived from food-processing plants. Eugene, Corvallis, and Albany extend treatment services to other jurisdictions and to industrial wastes.

Pulp and paper manufacture continues to dominate discharges, as it has for 50 years. Three quarters of the BOD_5 discharged to the Willamette originates with pulp mills. Another fifth comes from municipal sewage treatment plants. For two reasons, the relative municipal share of discharged wastes has been increasing continuously for at least 15 years. First, the percentage reduction in waste strength that pulp and paper mills can achieve through process modification and treatment is much greater than treatment technology affords to communities. Second, food processors and other industries have progressively shifted from direct discharge to sewering of their wastes, thus increasing the per capita waste load of municipal systems.

DATA AND METHOD

There is no shortage of data dealing with the quality of the Willamette River. Technicians, journalists, and politicians have for half a century covered pages with words and numbers on the subject. More than a dozen graduate students have written their theses about some aspect of the Willamette's water quality.

The first study of the quality of the river was prepared in 1929. Others followed in 1944, 1947, and 1948. In 1960, the U.S. Public Health Service began intensive monitoring of the Willamette. Three continuous automatic stream quality monitors were operated by State and Federal agencies between 1962 and 1967. In 1966 a comprehensive plan for the watershed, *Water Quality Control and Management, Willamette River Basin*, was issued jointly by the Oregon State Sanitary Authority and the Federal Water Pollution Control Administration. The State of Oregon has extensively monitored the stream for more than a decade; and a substantial portion of the official proceedings of the Oregon State Sanitary Authority (since superseded by the Oregon Department of Environmental Quality) deals with the river. Although the amount of data is great, EPA's Region X has found some deficiencies in the areas of runoff quality and of biological and physical data (Table X-3).

TABLE X-2

WILLAMETTE RIVER: POINT WASTE DISCHARGES (1972-73)

Discharger	River mile	Treatment	Flow (m.g.d.)*		BOD$_5$ (lb./day)		Phosphorus (lb./day)		Nitrogen (lb./day)†	
			Sewage	Industry	Sewage	Industry	Sewage	Industry	Sewage	Industry
Oregon Steel Mills	5			0.3				5		510
Rhodia Incorporated	5			0.7		1,130				165
Pennsalt Corp.	5			36.5		724		30		292
Milwaukie	18.5	Secondary	2.2		224		114		293	
Tryon Creek	21.1	Secondary	3.10		388		147		380	
Oregon City	25.4	Secondary	2.16		383		122		314	
West Linn #1	26.1	Secondary	0.45		53		68		175	
West Linn #2	26.1	Secondary	0.08		114		68		175	
Crown Zellerbach	26	Secondary		0.03		7,100		89		348
Publishers Paper	26	Chemical recovery – secondary		24.70		37,110				
Canby	34.4	Secondary	0.35		336		29		73	
Wilsonville	49	Secondary	0.10‡		14		8		21	
Newberg	50.0	Secondary	0.98		295		41		105	
Publishers Paper	50.0	Chemical recovery – secondary		10.4		6,100		575		4,090
Dundee	53.0	Secondary	0.04		7		4		11	
West Salem	79.6	Secondary	0.10		21		8		21	
Salem (Willow Creek)	83.6	Secondary	20.90		5,060		757		1,950	
Boise Cascade	83.6	Chemical recovery – secondary		0.05		8,010		325		34,500
Independence	96.0	Secondary	0.25‡		35		20		53	
Albany	119.0	Secondary	05.2		4,120		151		388	
Western Kraft	119.0	Chemical recovery – secondary		0.01		6,350		2		380
Corvallis	131.0	Secondary	06.4		1,540		285		734	
Evans Products	131.0			0.01		1,370		6		151
American Can Co.		Chemical recovery – secondary		13.4		1,340		613		1,370
Harrisburg	161.2	Secondary	0.15		326		10		25	
Eugene	180.0	Secondary	14.8		3,460		643		1,655	
Georgia Pacific	—			0.06		1,100		54		250
Totals			57.26	86.16	16,376	70,334	2,475	1,699	6,373	42,056

*Million gallons per day.

†Expressed as total nitrogen in industrial effluents, nitrate in sewage.

‡Estimated.

Chapter I describes the basic analytical method applied in this study of the Willamette River. Although no specific mathematical models are utilized in the exposition, it relies heavily on several models that have added considerably to understanding of the river.

WATER QUALITY CONDITIONS

Harmful Substances

Wastes from the heavy pulp and paper industries on the Willamette contain a pollutant called sulfite waste liquor. This pollutant is represented by the Pearl Benson Index (PBI), which measures the amount of wood phenols in solution. While scientists are not certain whether these phenols are directly toxic, experiments have shown that the metabolism of salmon swimming through zones of high PBI influence is upset. The salmon lose their equilibrium and behave erratically, exposing themselves to increased predation. The reaction becomes more pronounced as

TABLE X-3

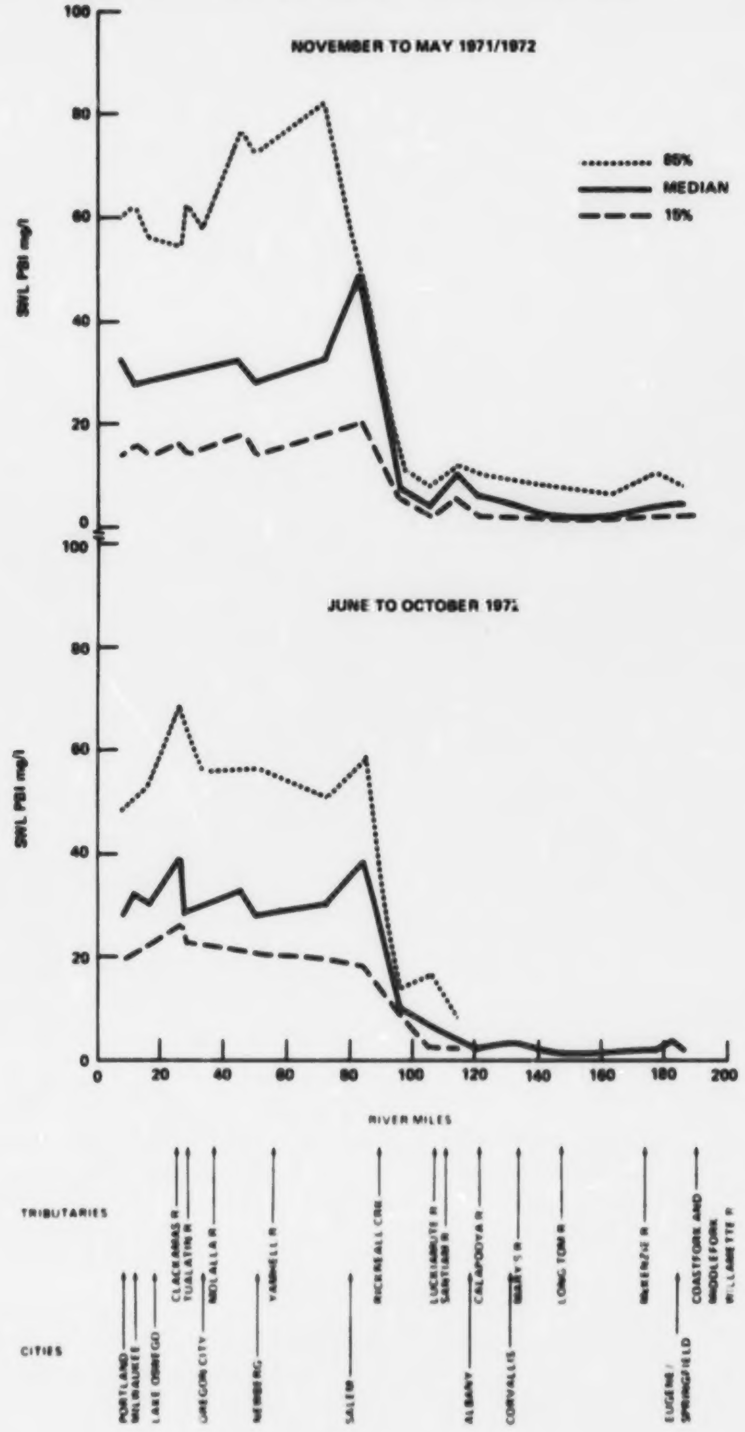
WILLAMETTE RIVER BASIN: MONITORING REQUIREMENTS

	Data uses				Data available
	Water quality trends	Waste load allocations	Modeling	Water quality standards	
Physical					
Receiving water		X	X		Yes
Reservoirs		X	X		Yes
Outfall information		X	X		Partial
Tributaries & diversions		X	X		Yes
Groundwater accretion		X	X		No
Meteorological		X	X		Partial
Water quantity					
Streamflow	X	X	X		Partial
Stage, tide	X	X	X		Yes
Point-source discharge		X	X		Partial
Nonpoint-source discharge		X	X		No
Lake & reservoir water levels	X	X	X		Yes
Water quality					
Carbon	X	X	X	X	BOD only; no COD, TOC, or TIC
Nutrients	X	X	X	X	Partial
Metals	X	X	X	X	Partial
DO, temperature, pH, and conductivity	X	X	X	X	Yes
Pesticides	X	X	X	X	No
Transfer ratio		X	X	X	No
Biological					
Phytoplankton & zooplankton	X				No
Benthic macroinvertebrates	X				No
Microorganisms	X	X	X	X	No
Algal & bioassays	X	X			No
Sediments					
Chemical composition	X	X	X		No
Particle size	X				No
Pesticides	X				No
Transfer ratio		X	X		No

temperature increases. There is also evidence that high PBI values impair normal avoidance mechanisms; as fish enter waters with high values, they become disoriented and continue to swim into waters with insufficient dissolved oxygen or excessive temperatures. In short, a high PBI may well be correlated with direct toxicity, but whether it is or is not, it correlates with an increase in mortality through a synergistic interaction with lowered dissolved oxygen, higher temperature, other toxins, and a promoted rate of predation. About 25 percent of the salmon population of the Columbia basin originates in the Willamette River.

Low (less than 5 mg/l) PBI values in the upper river rise slightly below the confluence with the McKenzie River, which caries the wastes of the Weyerhaeuser paperboard mill at Springfield (Figure X-5). With dilution and decay, the values subside, then rise again slightly in the Albany area, where the Western Kraft Co. mill discharges its

Figure X-5 SEASONAL RIVER PROFILES
WILLAMETTE RIVER
SULFITE WASTE LIQUOR-PEARL BENSON INDEX



effluent, and where the unassimilated wastes of Crown Zellerbach's Lebanon mill enter with the confluence of the Santiam River. Median values peak at 30 to 40 mg/l below Salem, where Boise Cascade's sulfite pulp plant is located, and continue at high levels to the mouth of the river. Small peaks occur at Newberg and Willamette Falls, where Publishers Paper Co.'s sulfite and groundwood pulping plants are located. Concentrations are generally lower in low flow periods, which may be due in some small measure to the effect of run-off from forest lands and industrial surfaces. It is probable, however, that production scheduling and other waste reducing techniques employed by pulp mills are limiting discharges in low flow months.

In the last 5 years, Willamette River pulp mills installed higher degrees of treatment. The result is that 1971-72 PBI values in the Willamette are now about half those of 1966-67 (Figure X-6). Flows have increased over the same period, contributing to the improved situation. During 1966-67, wastes were stored at low flows for later release. Today they are being treated and discharged. The effect is an overall reduction in PBI as well as BOD_5 and solids, but potentially higher levels of PBI during the period when waste storage formerly took place.

Physical Modification

Man's efforts have thoroughly altered the face of the Willamette Valley. The area is heavily urbanized and industrialized. The Willamette is dredged to 40 feet almost to RM 10 to handle ocean-going vessels. Locks have been installed at Willamette Falls, and the channel is maintained for barge traffic as far as Albany-Corvallis.

The major cities of the basin—Portland, Salem, Albany, Corvallis, Eugene—straddle the Willamette. A number of smaller communities sit on one bank or the other. Three major north-south highways parallel the river, and it is bridged in at least 20 places. There are dams on every significant tributary. Log hauling and log storage are important navigational activities. Recreational boating is popular.

Sediment Production. The Willamette at high flow is probably among the most turbid of the major rivers of the West, although less turbid than the Potomac or the rivers of the Southeast. Erection of dams and reservoirs has trapped some silt, but the phenomenon has persisted. Average annual sediment production of the Willamette is 5.5 million tons (Table X-4). At high flows, solids concentrations have ranged from 400 to 1,000 mg/l below Salem, and twice those levels in Portland harbor.

TABLE X-4

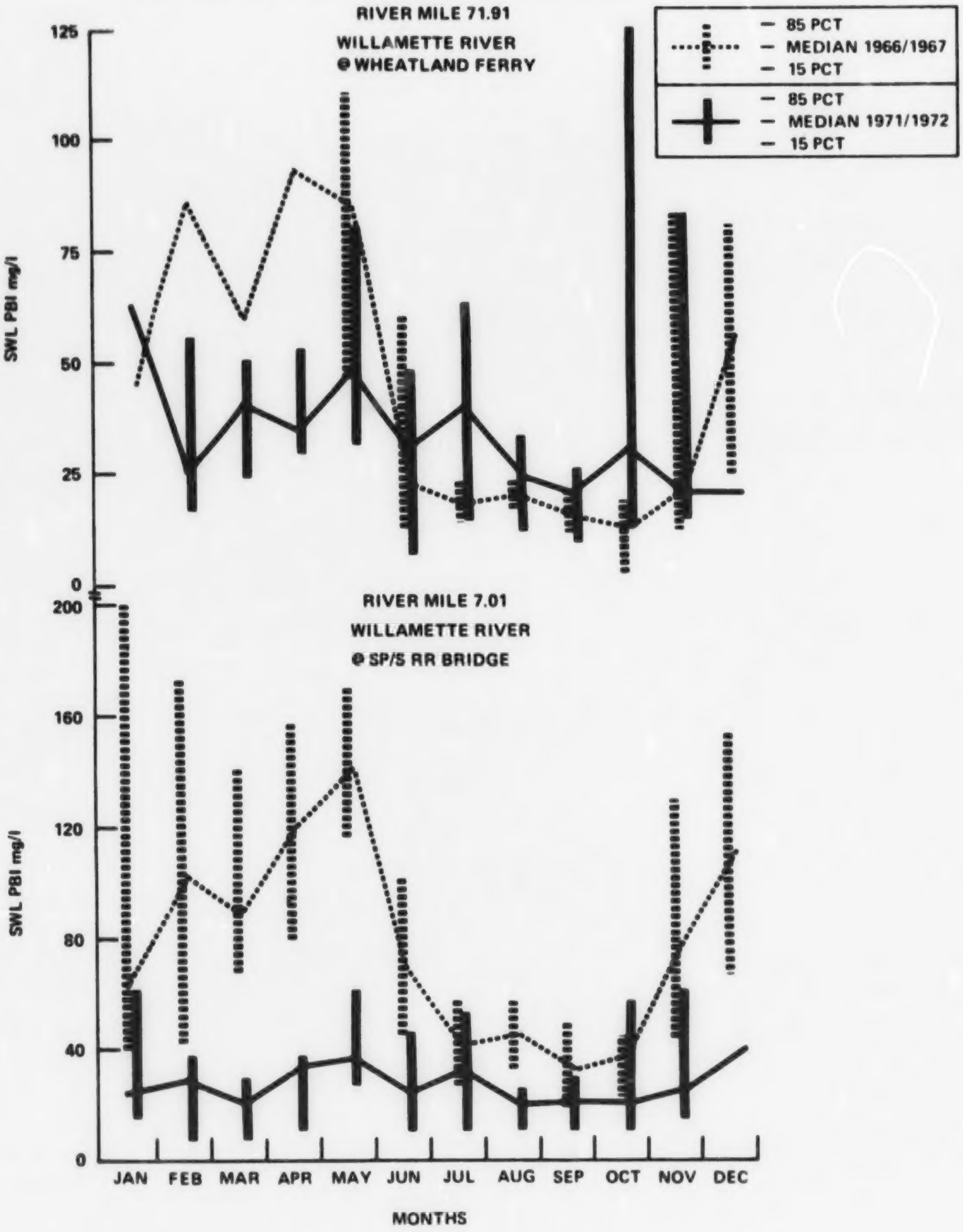
WILLAMETTE RIVER SEDIMENT LOADS (1963)

Source	Tons/sq. mile	Square miles	Tons at mouth	Percent of total sediments
Bank cutting and channel scouring			2,200,000	40
Agriculture	400	2,800	1,120,000	21
Construction	40,000	26	1,060,000	19
Forest, actively logged	40,000	25	1,000,000	17
Forest	20	7,950	160,000	3
Total		10,801	5,540,000	100

Figure X-6 **TIME TRENDS AT RIVER MILEPOINTS**

WILLAMETTE RIVER

SULFITE WASTE LIQUOR-PEARL BENSON INDEX



Man's activities produce about 60 percent of the sediment:

- Agriculture (21 percent) yields sediment from crop lands. Cropping patterns and agricultural practices limit sediment production significantly.
- Construction (19 percent) adds to sediment loads, especially in areas with paved surfaces and storms drains.
- Forest logging (17 percent), which produces 3 billion board feet a year, accelerates erosion on the steep forested slopes of the basin. Logging practices in the past 30 years have sharply reduced but not eliminated the problem. (Among the methods of controlling erosion from logging are clear cutting and highline log handling. These practices partially denude hills, but reduce soil disturbance and promote reestablishment of vegetative cover during reforestation.) Natural bank erosion and bottom scour produce the remaining 40 percent of the load.

Temperature. The principal influences on temperature of the Willamette are climate and hydrology. Waste discharges probably have only a marginal effect. Oregon's temperature criteria for the Willamette River are repeatedly exceeded in summer. The criteria require no measurable increase due to discharges when stream temperature exceeds 21.1°C (70°F) below Newberg or 17°C (64°F) above Newberg. Temperatures rise steadily over the entire length of the river. The most marked increase in temperature occurs in the stretch of river between the confluence with the Long Tom and Salem. In that 50 miles, the placid river courses between bare banks, absorbing the heat of the sun and achieving a substantial balance with ambient air temperatures. Below Salem, temperature increase is promoted as flow rate decreases in the Newberg Pool and as several of the smaller, warmer, western tributaries enter the Willamette. In the Newberg Pool, the temperature criterion is often exceeded (Figure X-7).

Eutrophication Potential

The Willamette River exhibits neither the discoloration nor day-night variation in dissolved oxygen concentrations that characterize an over-productive stream, and there are no reports of excessive algae. On the other hand, *Sphaerotilus* growths have been detected in the area of Willamette Falls and near Eugene, and all of the Willamette's western tributaries are excessively productive.

Available nutrients are more than sufficient to produce nuisance growths of algae. Nitrogen concentrations exceed the theoretical 0.3 mg/l threshold from approximately RM 120 during high flows, and during the low-flow period, when the water is clear and temperatures are warm, median levels are even higher (Figure X-8).

Similarly, concentrations of dissolved phosphorus are significantly higher than the indicated algae control level over the length of the stream and throughout the year, especially at low flow. Thus phosphorus availability is greatest when other environmental conditions are most favorable for production of algae (Figure X-9).

The inverse relationship of streamflow to nitrogen and phosphorus concentrations indicates strongly discharge-related sources. However, spring and fall upsurges of phosphorus concentrations are consistent with a pattern of reservoir turnover induced by temperature change and reservoir evacavation at those times (Figure X-10). Both point source discharges and reservoir turnovers are probably implicated. Phosphorus concentrations apparently decreased from 1966-67 to 1971-72, but this way may be a result of higher flows.

In any event, even though nitrogen and phosphorus are present, algae do not occur in nuisance amounts. Quite clearly, nutrients are not the limiting factor in the Willamette's biotic balance. Given the known turbidity of the stream, it is possible that not enough light penetrates to stimulate the biological productivity of the river to nuisance levels.

Salinity, Acidity, and Alkalinity

The waters of the Willamette are low in dissolved mineral salts, and their pH is very close to neutral. Dissolved solids concentrations average about 60 mg/l, and even in the smallest tributaries they seldom exceed 100 mg/l.

Figure X-7 **SEASONAL RIVER PROFILE**
WILLAMETTE RIVER
WATER TEMPERATURE

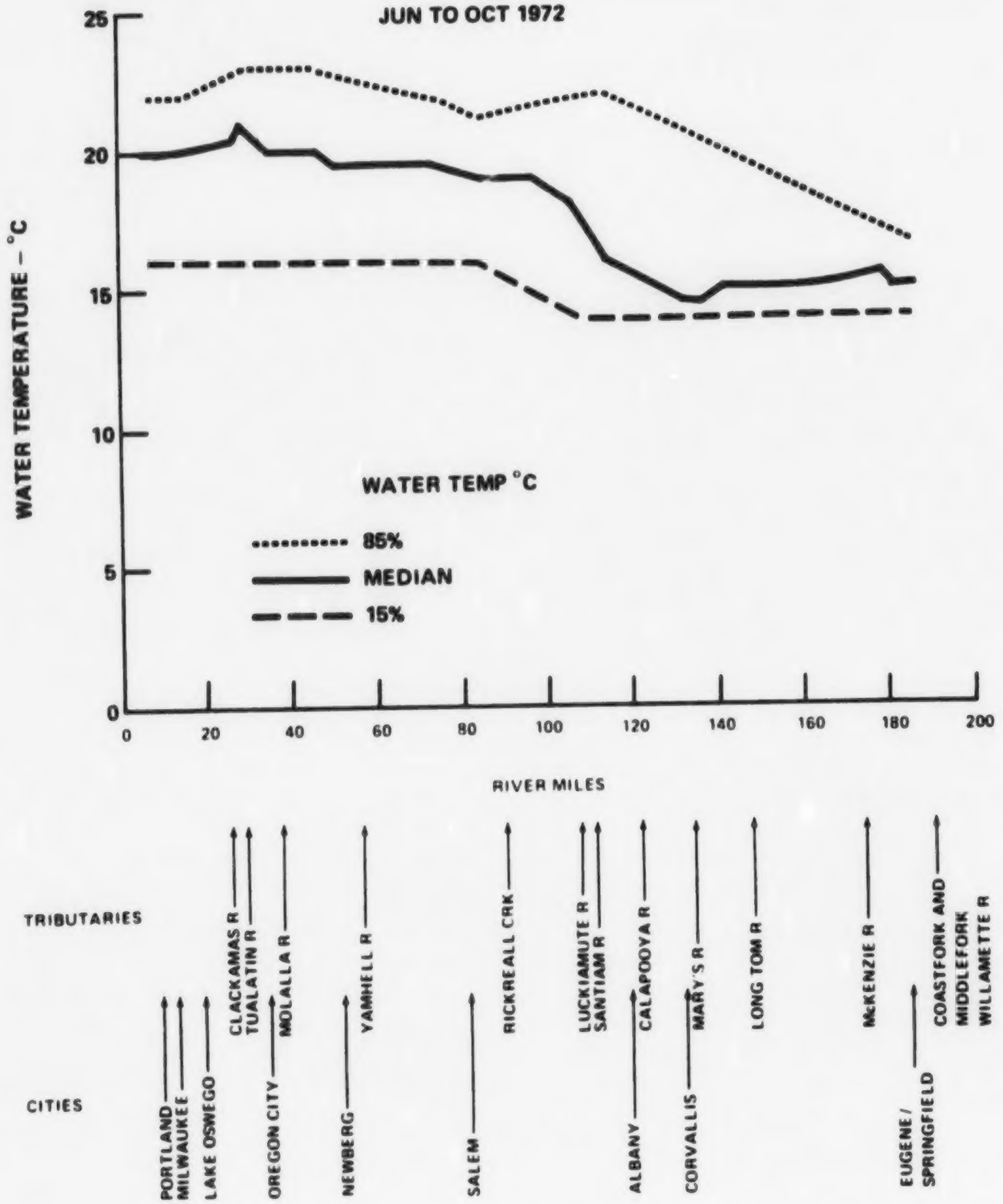


Figure X-8 **SEASONAL RIVER PROFILE**

WILLAMETTE RIVER

TOTAL NITRATE

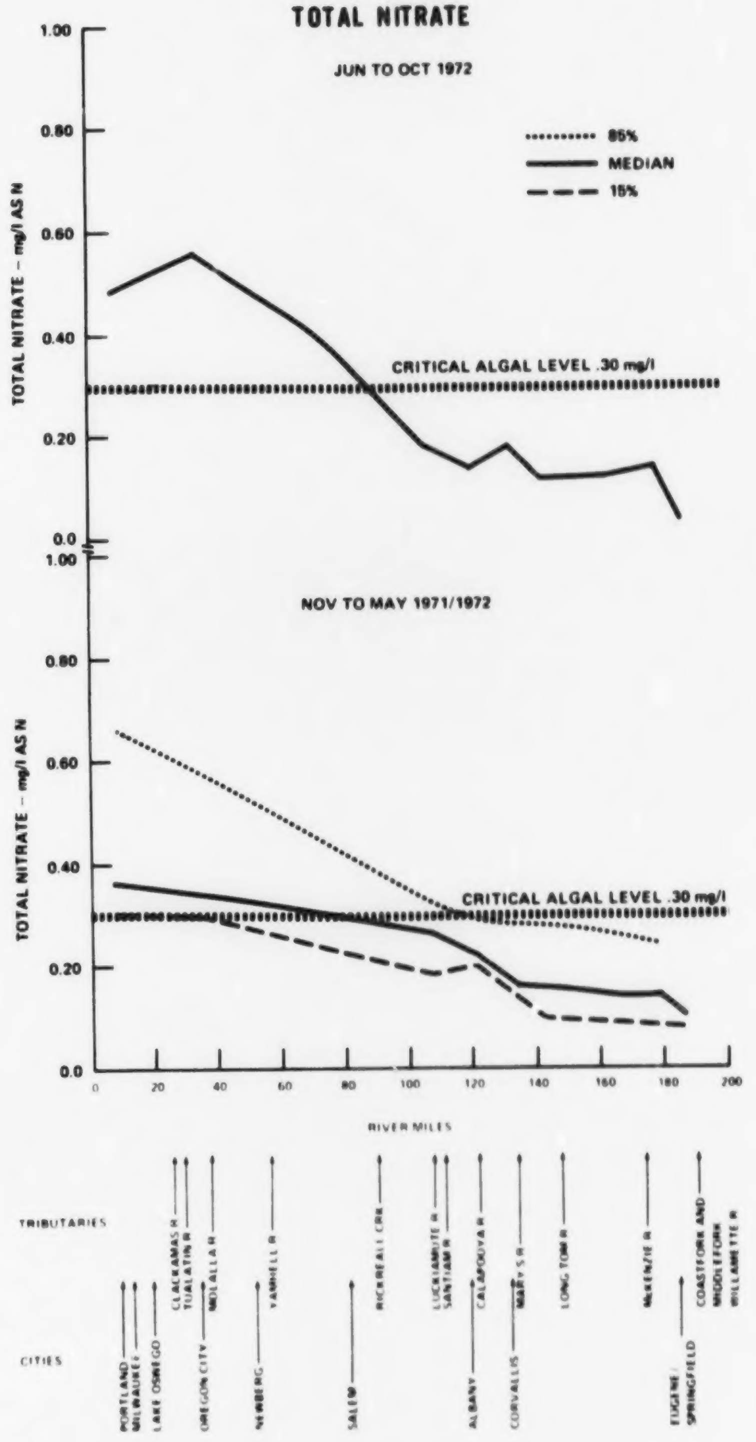


Figure X-9 **SEASONAL RIVER PROFILES**
WILLAMETTE RIVER
ORTHOPHOSPHATE

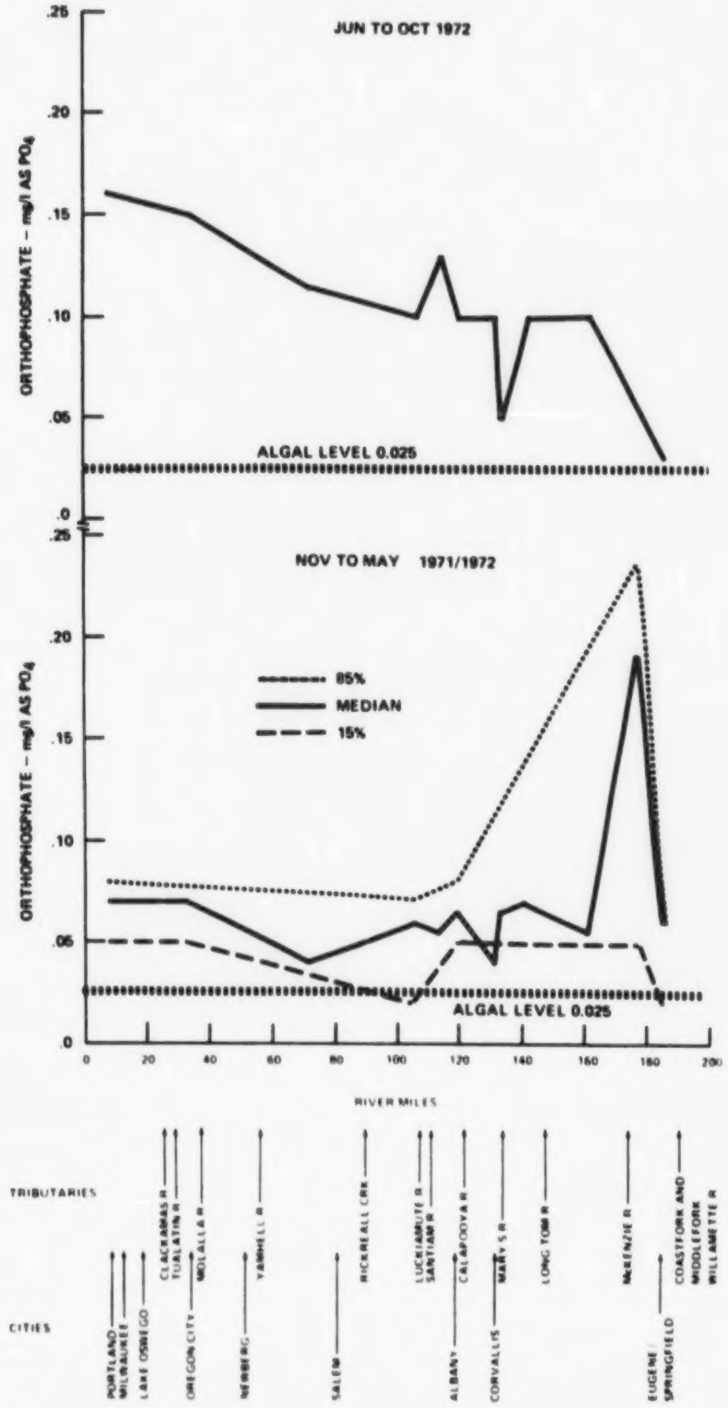
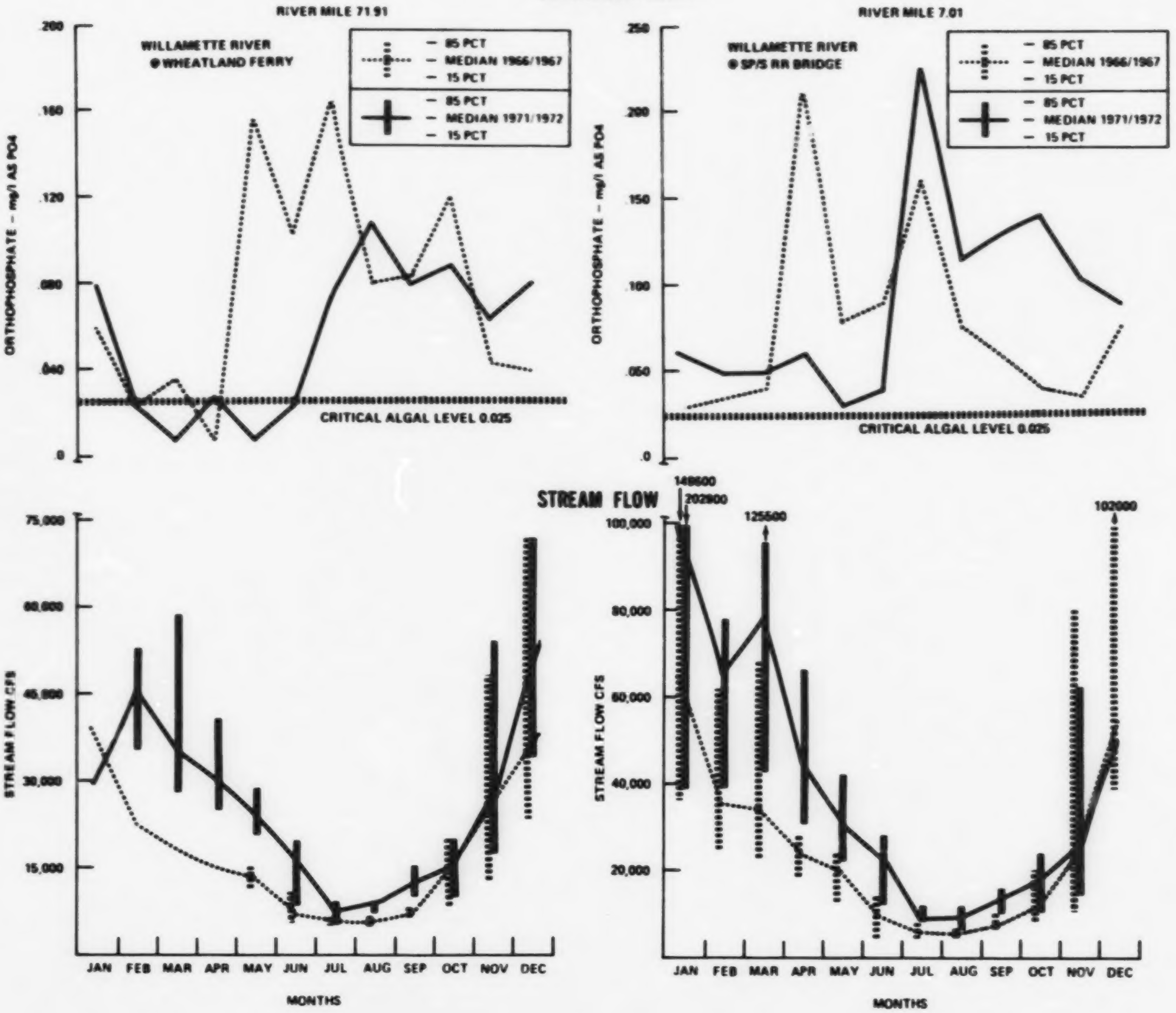


Figure X-10 **TIME TRENDS AT RIVER MILEPOINTS**

WILLAMETTE RIVER

ORTHOPHOSPHATE



Acidic industrial discharges have produced a few scattered violations of the allowable pH criteria (6.5 to 8.5). In 1972, 11 violations at nine locations were observed—only 1 percent of all samples taken. Increasing industrial waste treatment has brought about a distinct reduction in the incidence of violation (Table X-5).

Oxygen Depletion

Restoration of dissolved oxygen concentrations sufficient to support the life processes of salmon over the length of the river at all times during the year is the most notable achievement of the clean-up of the Willamette River. The dissolved oxygen criteria call for at least 5 mg/l (adequate for migration and adult habitat for salmonid fish) through Portland Harbor, 6 mg/l through the Newberg Pool, 7 mg/l from Salem to the Newberg Pool, and 90 percent of saturation for all areas, including the main stem above Salem, in which salmon spawn.

During high flows the Willamette has always met those standards. (Indeed, Portland Harbor, which has been the critical point for dissolved oxygen during low flows, is supersaturated under high flow conditions as a result of reoxygenation at Willamette Falls). With the waste regulations in effect, the Willamette now meets the dissolved oxygen criteria even at extreme low flow, and the low point for dissolved oxygen concentrations has been restored to its natural location about 20 miles upstream (Figure X-11). Dissolved oxygen concentrations are lowest at low flow, generally, in August, with highest concentrations during the December-January flood (Figure X-12).

More significant, however, is the fact that the whole range of concentrations has shifted upward in the past 5 years. Median concentrations in Portland Harbor, and even below Salem, have improved 1 to 3 mg/l in that period. The higher values of 1971-72 coincided with higher flows, but the summer of 1973 demonstrated that the upward shift in dissolved oxygen concentrations is due to something more fundamental than cyclical fluctuations in streamflow. In 1973, the Pacific Northwest experienced its worst drought on record. In spite of the attenuation of streamflow (which was somewhat relieved by reservoir storage), the lowest dissolved oxygen level recorded in Portland Harbor was 5.2 mg/l—greater than the highest recorded August value of the 1940's and 1950's.

Health Hazards and Aesthetic Degradation

Oregon's bacterial standard for the Willamette River includes a requirement that total coliform counts are not to exceed 1,000 organisms per 100 ml. The standard is seldom met. Median counts are in the 2,500 to 3,500 range over most of the river during low flow, roughly twice that at high flow (Figure X-13).

Because the numbers of bacteria are higher when flows are high, runoff, rather than discharge, is probably the principal influence on bacterial populations. Lowest levels occur in and below Newberg Pool and in summer—that is, bacterial quality is best where maximum population and discharge are concentrated and at the place and times that the pollution of the river has been most pronounced. The phenomenon is not readily explainable, although it is possible that ponding and reduced velocity promote die-off.

TABLE X-5

SNAKE RIVER pH CRITERIA VIOLATIONS

	1963	1968	1972
Locations monitored	18	30	24
Percent with one or more pH criteria violations	55.5%	43.3%	37.5%
Number of pH determinations	428	1,809	1,080
Percent with violations	8.9%	3.4%	1.0%

Figure X-11 SEASONAL RIVER PROFILES
WILLAMETTE RIVER
DISSOLVED OXYGEN

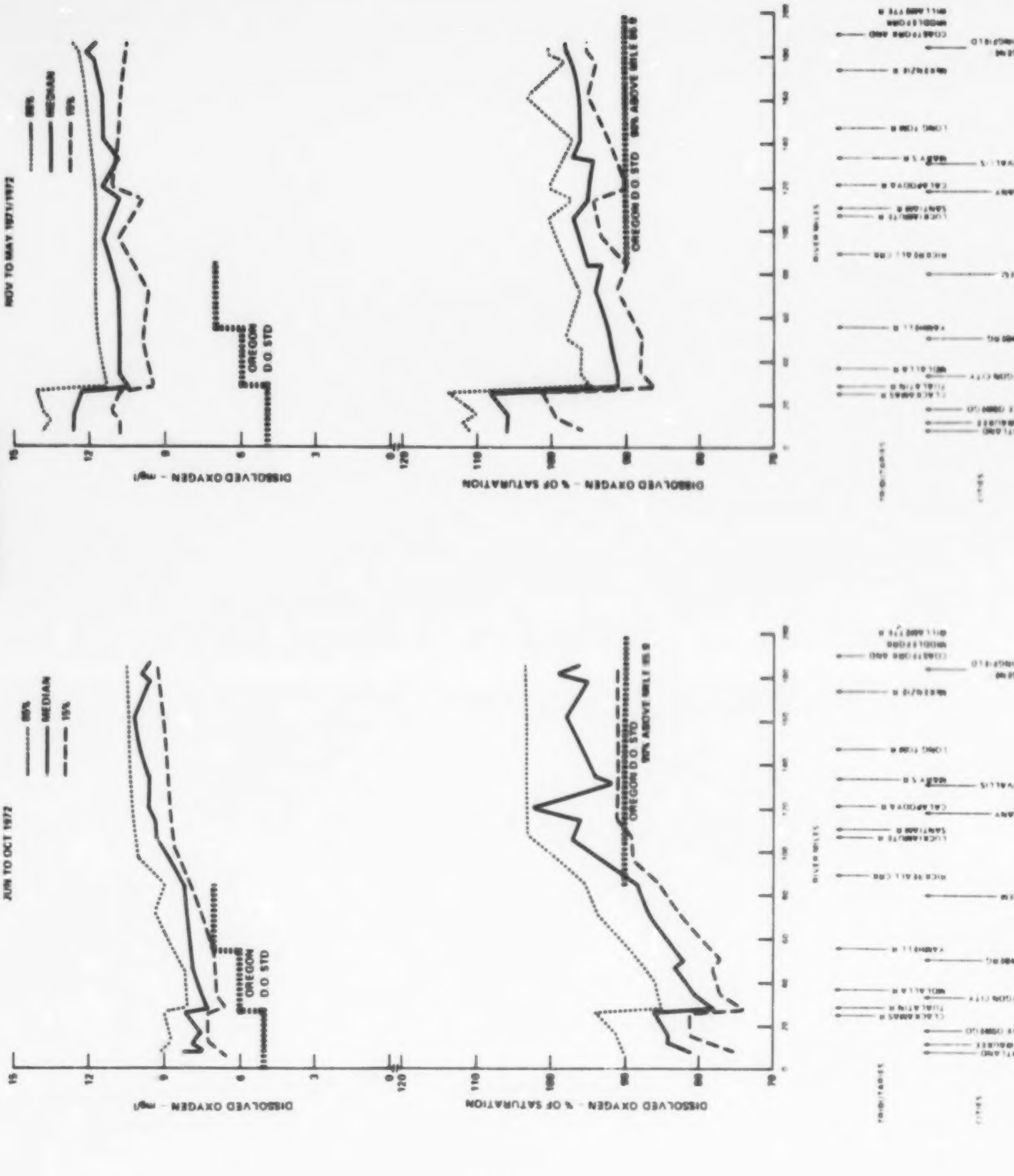
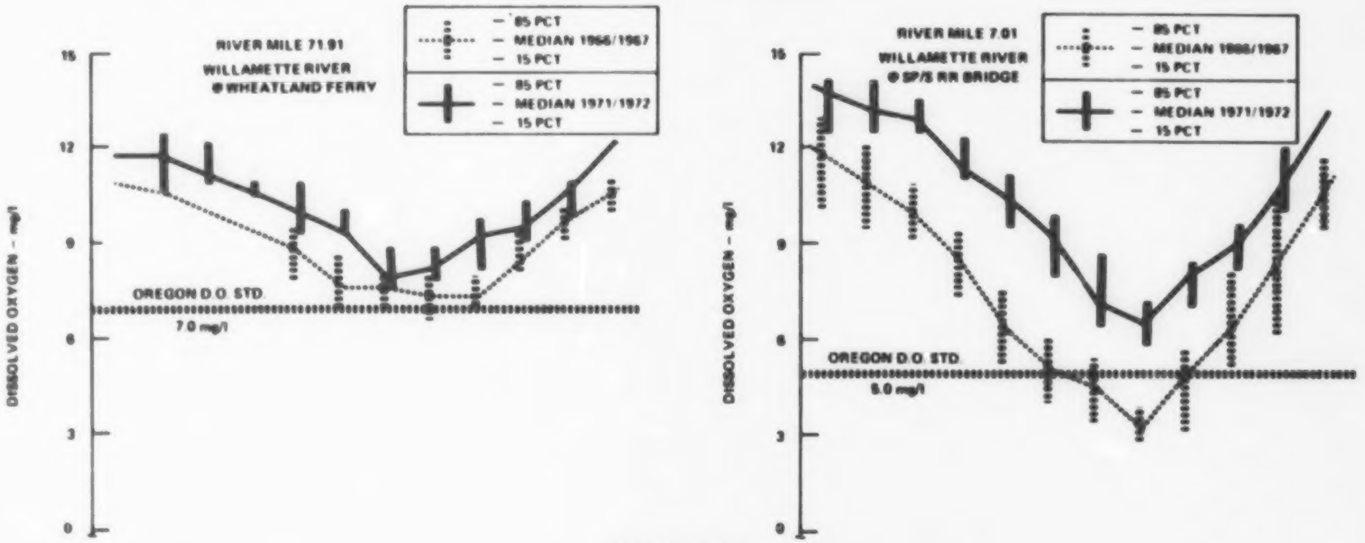


Figure X-12 TIME TRENDS AT RIVER MILEPOINTS

WILLAMETTE RIVER

DISSOLVED OXYGEN



STREAM FLOW

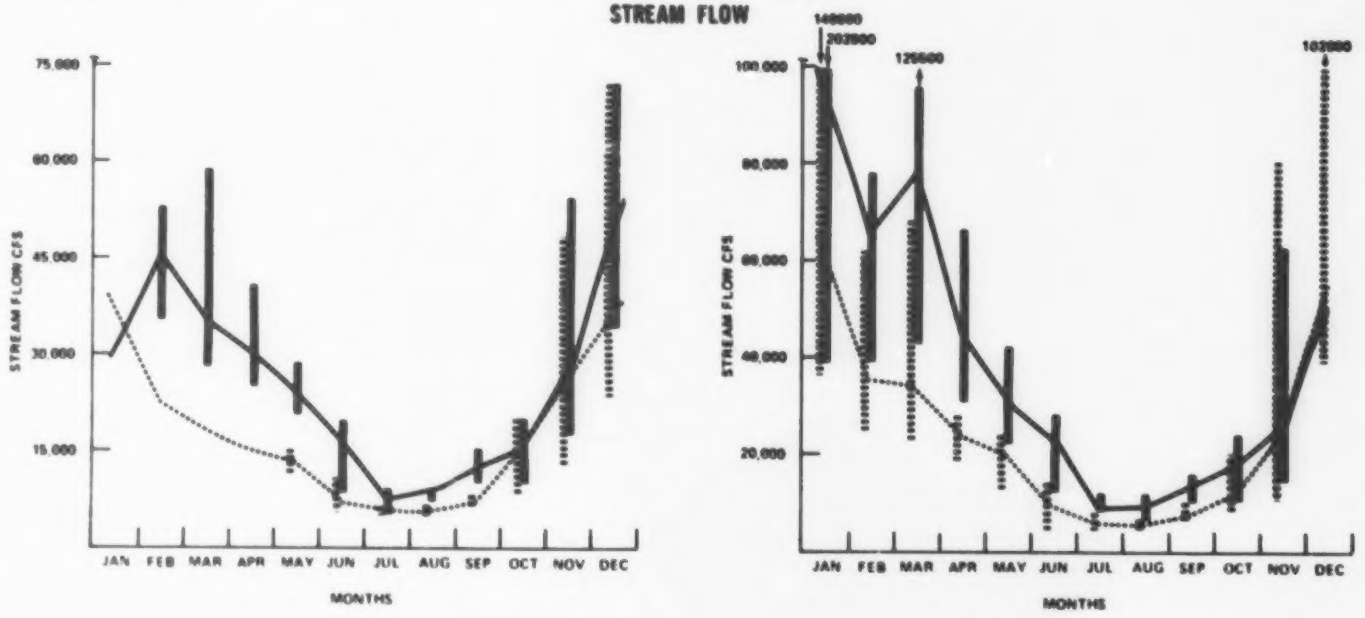
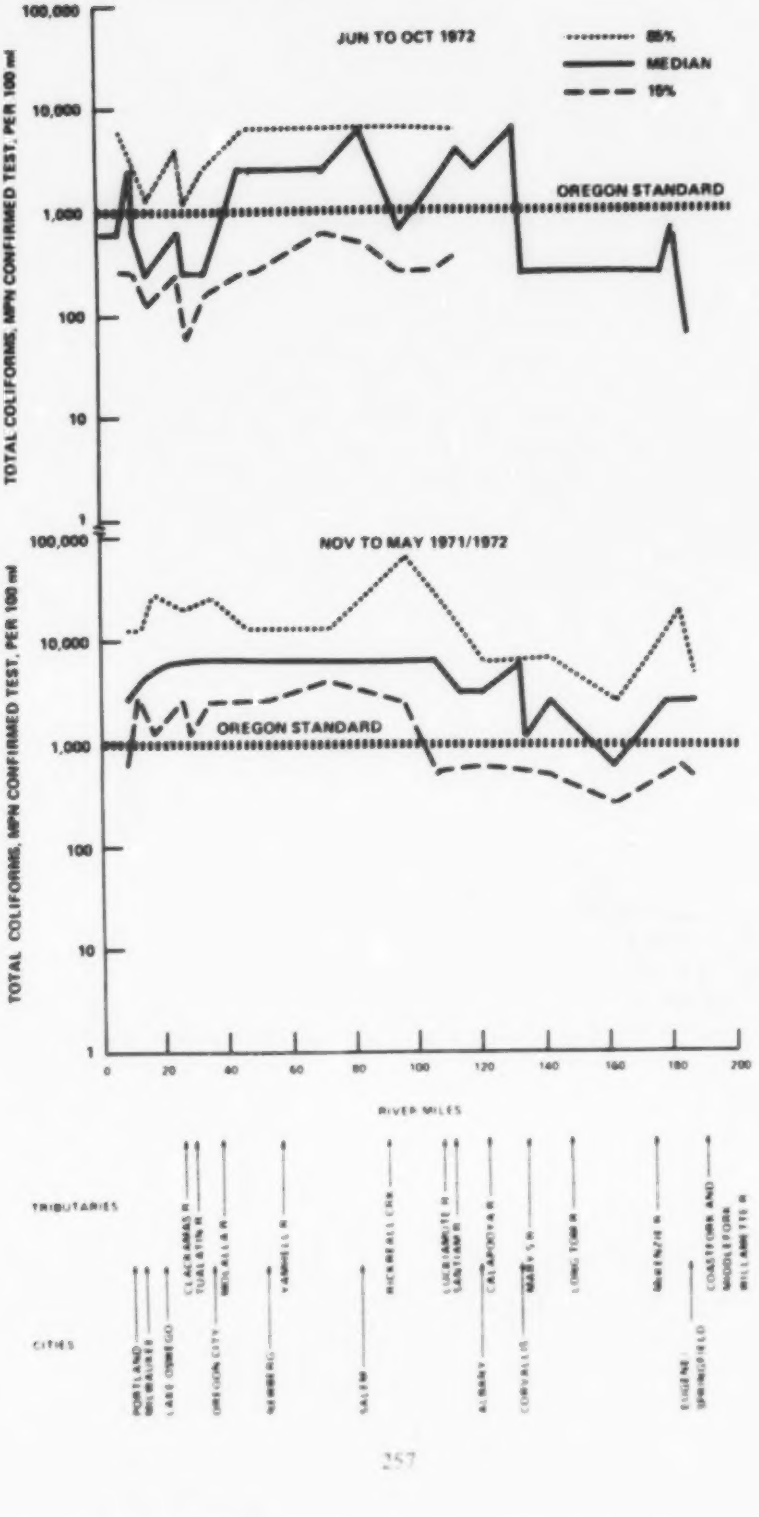


Figure X-13 **SEASONAL RIVER PROFILES**
WILLAMETTE RIVER
TOTAL COLIFORMS



Although the flow/bacteria relationship for total coliforms suggests natural causes, it is unsettling to find that the relationship extends to fecal coliform concentrations (Figure X-14). On the basis of values at Oregon's standard monitoring stations, there appears to be a fairly constant 10:1 ratio of total to fecal coliform at median values for each, and both fecal and total coliform determinations rise with streamflow. Possible explanations include the influence of the watershed's substantial population of farm and domestic animals, effects of combined sewers or treatment plant overloading, less intensive disinfection in seasons when water contact recreation is not practiced, or lack of precision in the fundamental methods of determination.

The location of peak fecal coliform concentrations is also anomalous. High values occur below Eugene and Salem, but the highest values at least in the flow period are found in the sparsely settled area between Eugene and Corvallis. (The circumstance provides some support for speculation that the substantial cattle herds in the area may be the source.)

An intensive bacterial survey was conducted in the summer of 1968 (Figure IX-15). The survey by the Oregon State Sanitary Authority in cooperation with the Federal Water Pollution Control Administration found that:

- Known bacterial peaks subsided swiftly, particularly in dry weather (July).
- The ratio of total to fecal coliforms varied from less than 10:1 to greater than 11,000:1.
- Pulp paper waste discharges were a significant source of bacteria.
- Runoff correlated with increasing bacterial populations.
- The ratio of total to fecal coliforms did increase with runoff.

Bacterial quality, like dissolved oxygen, would seem to be improving. Although the total coliforms standard continues to be exceeded more often than met, 1971-72 counts were distinctly lower than 1966-67 counts, in spite of higher flow in the later period (Figure X-16).

PROJECTION

The satisfactory quality of the waters of the Willamette River is the result of a delicate technological balance. Current regulatory policies seem to be fully adequate for existing conditions. There is some question that natural phenomena will ever permit full compliance with bacteria, turbidity, and temperature standards, but those deficiencies should not affect fishing or recreation.

Threats to the water quality of the river lie in the degree of development and rate of growth in the Willamette Valley. Also, since the critical change in the river environment was augmentation of summer streamflow by releases from storage reservoirs, water quality could become worse if more water were diverted for irrigation or evaporative cooling. Western water law provides the right to divert and use water for "beneficial" purposes, and there is little constraint on such use. Conversely, there is little legal protection for in-stream water use. Significant expansion of either irrigation or evaporative cooling could jeopardize the artificial summer flow upon which the continued health of the Willamette depends.

In the short run, the quality of the Willamette River is adequately controlled. But for the longer term, the environmental carrying capacity of the river seems threatened by the pace, and perhaps direction, of development.

RECOMMENDATIONS FOR MONITORING

The State of Oregon maintains an extensive monitoring network on the Willamette River, the physical and chemical relationships governing the system are generally understood, and the current status of the stream's water quality is excellent. For all these reasons, the river would seem to have a low priority for additional monitoring. On the other hand, the State of Oregon and EPA agree that more data on nonpoint sources are necessary. Therefore, EPA has scheduled significant resources in 1974 to assist the State in redesigning its monitoring program to place more emphasis on identifying nonpoint sources.

Figure X-14 SEASONAL RIVER PROFILES

WILLAMETTE RIVER

FECAL COLIFORMS

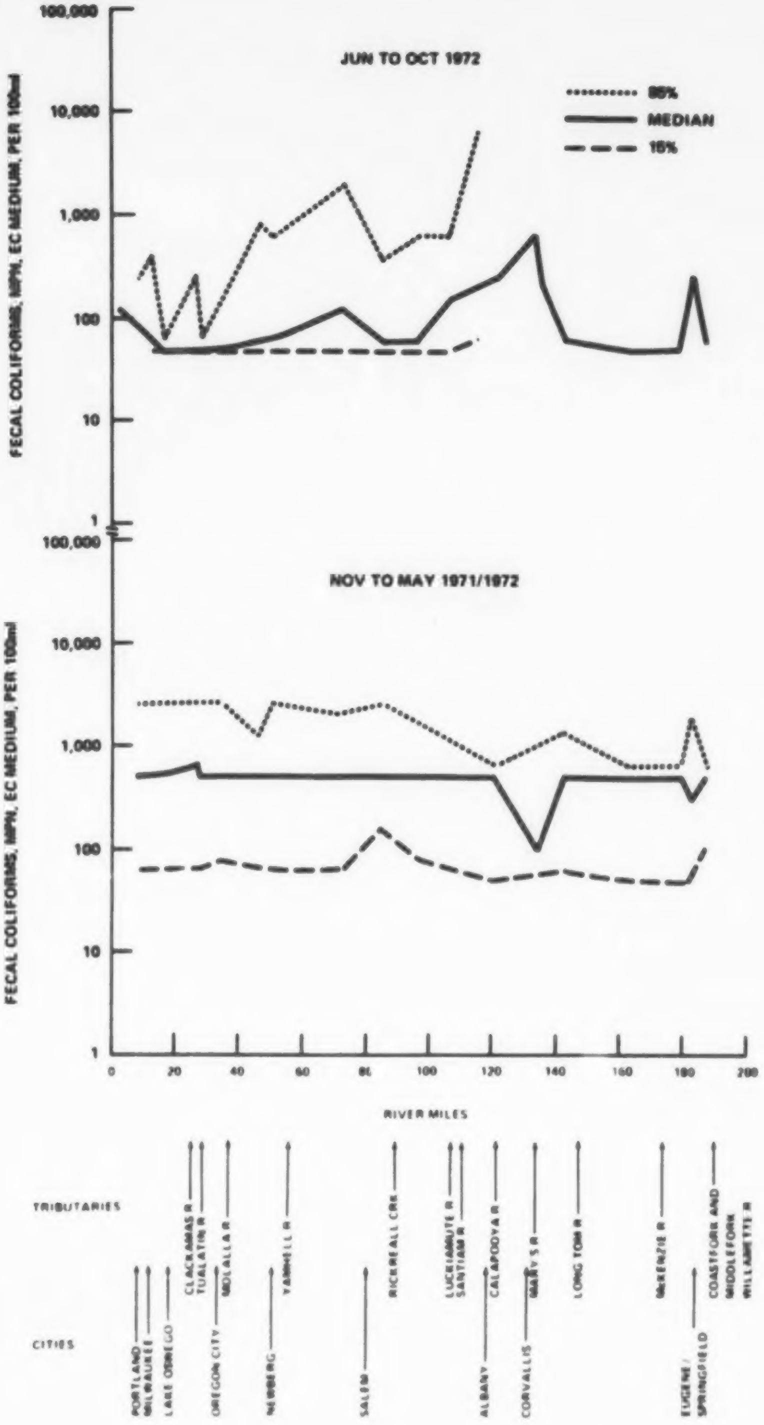


Figure X-15 SEASONAL RIVER PROFILES

WILLAMETTE RIVER

COLIFORMS

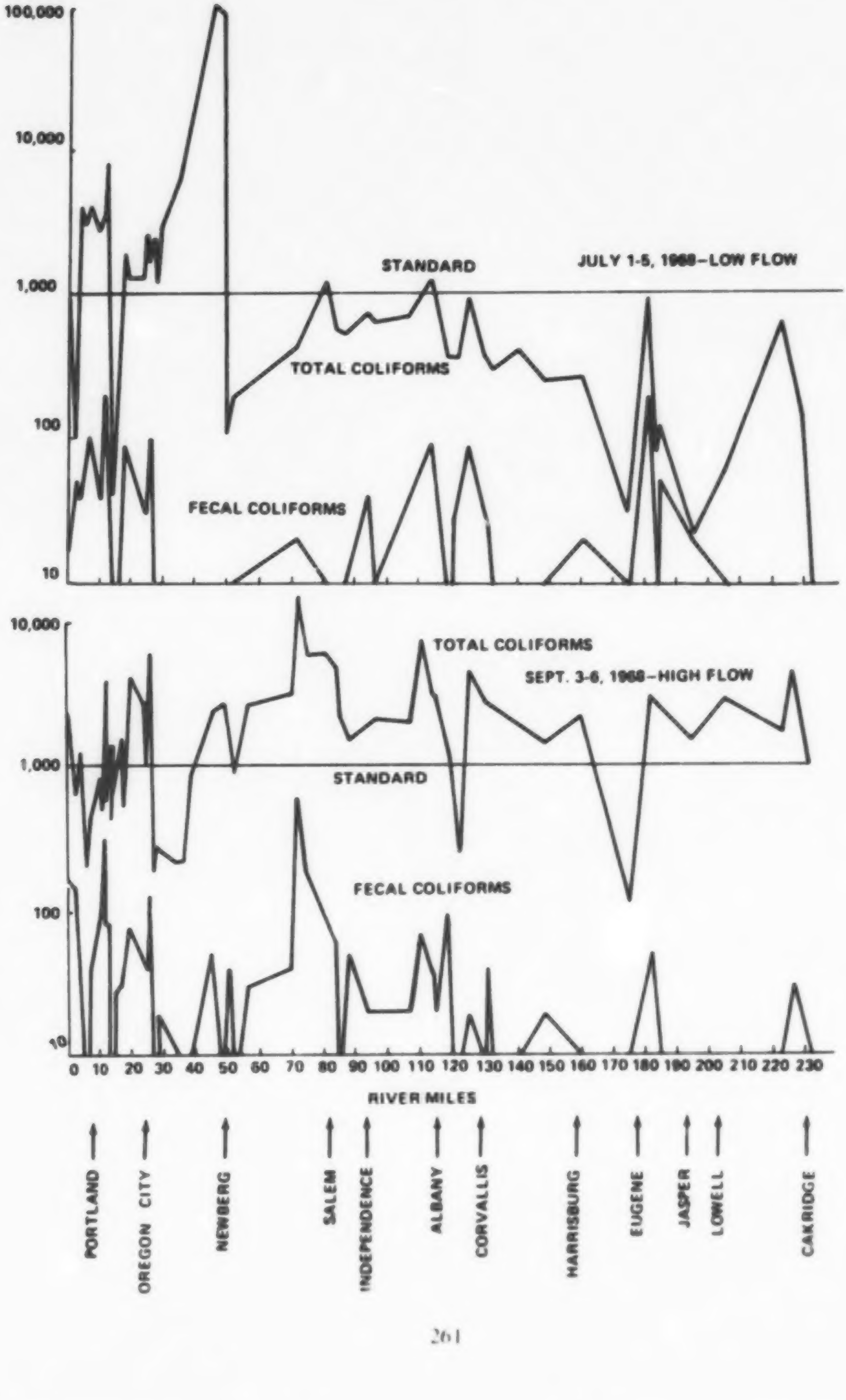
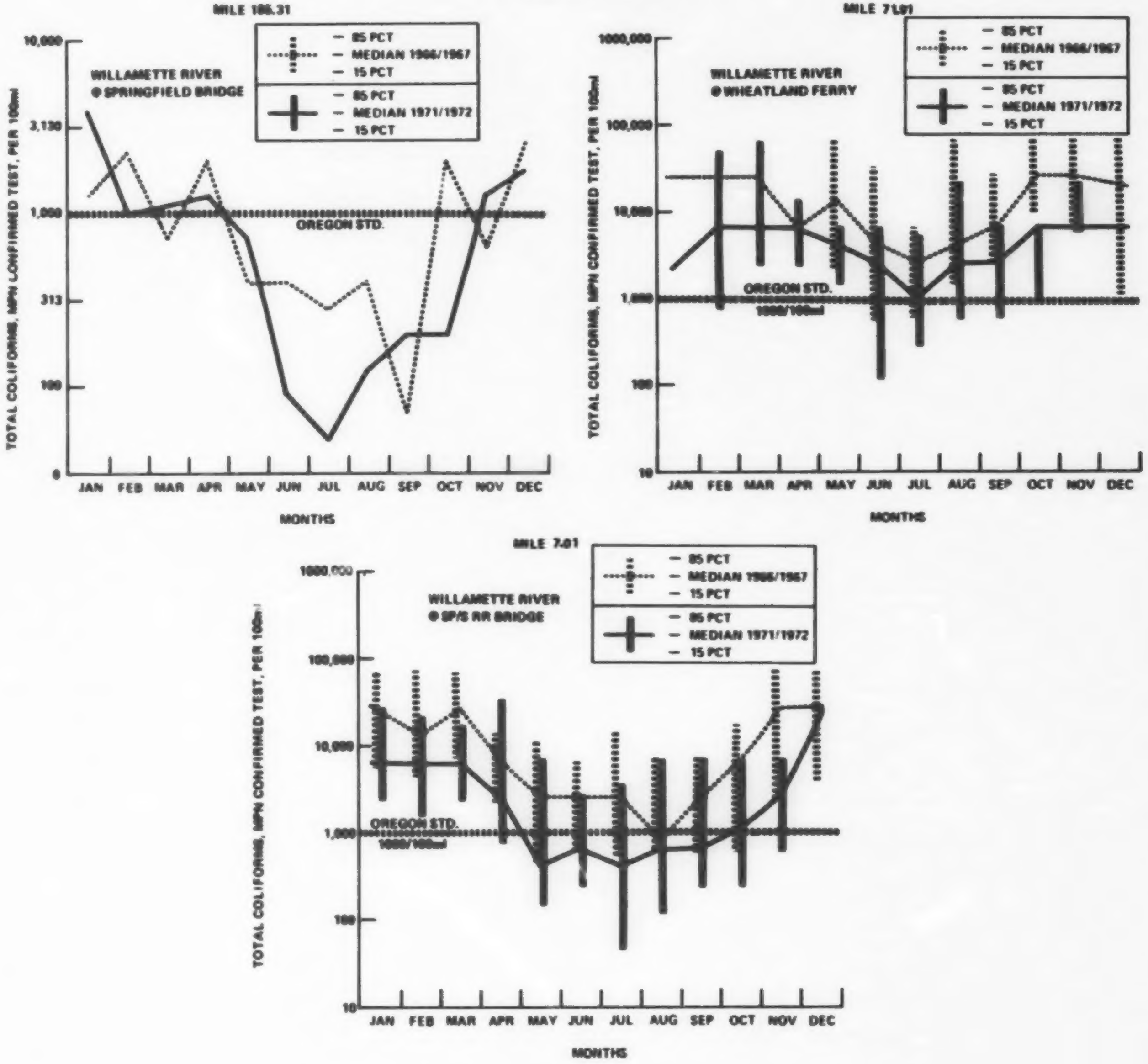


Figure X-16 TIME TRENDS AT RIVER MILEPOINTS
WILLAMETTE RIVER
TOTAL COLIFORMS



PART II

POINT SOURCE INVENTORY

XI. POINT SOURCE INVENTORY

The 1972 Act prohibits all point source discharges into the Nation's waters without a permit. Point sources, except agricultural sources, are defined as discharges through pipes or discrete conveyances. Agricultural point sources include large feedlots, irrigation return flows and fish hatcheries, but do not include most agricultural operations that produce dispersed runoff. Specific point sources may be categorized as municipal waste treatment facilities, industrial/commercial sources, agricultural sources, and Federal facilities.

Point sources may not be the worst sources of pollution in every location; but since control methods for them are generally available now, Congress created a National Pollution Discharge Elimination System (NPDES) to issue permits to each point source specifying the allowable discharge limits for specific pollutants.

EPA expects to receive approximately 75,000 applications for NPDES permits from point sources. As of March 1974, about 41,000 permit applications had been received and 5,100 permits had been issued (Table XI-1).

TABLE XI-1

U.S. WATERWAYS; POINT SOURCE DISCHARGES

	Industrial/ commercial*	Municipal*	Agricultural*
Applications expected	32,000	31,000-36,000+	6,500
Applications received for processing	24,500	15,600	1,200
Permits issued	3,900	1,200	

*Federal facilities are included in these categories.

+Includes 10,000 to 15,000 privately-owed treatment works.

MUNICIPAL WASTE TREATMENT FACILITIES

EPA's inventory of municipal point sources, begun in 1940 and updated through February 1974, shows that there are approximately 21,000 municipal waste treatment facilities in the United States. The great bulk of these facilities are in small communities: over 50 percent serve populations less than 1,000; less than 1 percent serve populations greater than 100,000 (Table XI-2).

These facilities generally practice one of three different levels of biological waste treatment:

- Primary treatment plants take raw sewage and separate the particulate matter from the water by settling the heavier solids and skimming off the lighter ones. This process normally removes 20 to 35 percent of the BOD_5.

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TABLE XI-2

MUNICIPAL DISCHARGES BY STATE

STATE	Number of municipal facilities by treatment level							Number of facilities by population served			
	Total	Primary	Adequate secondary	Inadequate secondary	Unclassified secondary*	Tertiary	None	Less than 1,000	1,000 to 9,999	10,000 to 100,000	Greater than 100,000
ALABAMA	261	32	65	42	101	0	21	96	137	27	1
ALASKA	38	8	0	1	25	0	4	31	4	2	1
ARIZONA	119	3	7	13	75	1	20	51	54	11	3
ARKANSAS	211	18	5	29	157	0	2	71	118	21	1
CALIFORNIA	659	119	69	62	375	11	23	196	300	140	23
COLORADO	233	11	15	16	168	7	16	119	86	24	4
CONNECTICUT	180	39	11	7	84	6	33	88	44	45	3
DELAWARE	25	5	8	8	2	0	2	8	15	1	1
DISTRICT OF COLUMBIA	1	0	0	1	0	0	0	0	0	0	1
FLORIDA	582	40	173	147	189	14	19	261	240	78	3
GEORGIA	474	64	207	114	62	2	25	264	173	33	4
HAWAII	39	5	9	3	15	0	7	11	22	6	0
IDAHO	129	17	16	42	37	0	17	67	53	9	0
ILLINOIS	828	71	183	230	287	31	26	313	416	92	7
INDIANA	741	43	37	80	355	104	122	450	241	44	6
IOWA	639	27	23	122	350	0	117	421	195	22	1
KANSAS	632	98	13	67	442	0	12	405	192	33	2
KENTUCKY	284	25	6	5	238	3	7	96	166	20	2
LOUISIANA	188	11	1	2	159	0	15	42	111	33	2
MAINE	68	15	4	3	24	0	22	27	34	7	0
MARYLAND	304	28	61	57	141	0	17	195	88	19	2
MASSACHUSETTS	153	37	0	0	77	0	39	56	56	33	8
MICHIGAN	482	108	59	58	132	13	112	184	245	48	5
MINNESOTA	520	53	15	92	311	15	34	295	195	27	3
MISSISSIPPI	312	7	4	11	277	0	13	170	114	27	1
MISSOURI	454	20	18	31	376	0	9	213	205	30	6
MONTANA	163	24	2	2	127	2	6	109	46	8	0
NEBRASKA	496	41	4	24	385	7	35	374	109	10	3
NEVADA	39	3	7	2	24	1	2	14	21	1	3
NEW HAMPSHIRE	45	18	0	2	23	0	2	10	26	9	0
NEW JERSEY	339	84	20	33	193	4	5	73	176	80	10
NEW MEXICO	82	1	8	27	45	0	1	27	39	14	2
NEW YORK	747	472	34	66	135	16	24	312	329	86	20
NORTH CAROLINA	1,156	114	150	166	634	33	59	901	200	53	2
NORTH DAKOTA	256	15	3	11	216	0	11	194	54	8	0
OHIO	1,033	89	219	123	298	132	172	576	344	101	12

TABLE XI-2–(Continued)

MUNICIPAL DISCHARGES BY STATE

STATE	Number of municipal facilities by treatment level							Number of facilities by population served			
	Total	Primary	Adequate secondary	Inadequate secondary	Unclassified secondary*	Tertiary	None	Less than 1,000	1,000 to 9,999	10,000 to 100,000	Greater than 100,000
OKLAHOMA	385	12	76	157	137	0	3	199	155	28	3
OREGON	249	42	39	54	91	2	21	117	102	28	2
PENNSYLVANIA	1,877	164	429	263	494	253	274	1,225	518	121	13
RHODE ISLAND	27	8	1	7	2	2	7	11	6	8	2
SOUTH CAROLINA	1,416	113	37	93	1,067	82	24	1,202	188	25	1
SOUTH DAKOTA	227	19	93	74	26	2	13	169	50	8	0
TENNESSEE	265	17	60	42	134	6	6	102	133	26	4
TEXAS	911	73	172	490	[illegible]	1	4	239	530	123	19
UTAH	89	14	23	21	[illegible]	1	13	42	29	16	2
VERMONT	79	34	1	4	31	0	9	34	41	4	0
VIRGINIA	956	99	54	90	673	22	18	733	184	31	8
WASHINGTON	363	95	22	39	182	2	23	202	120	37	4
WEST VIRGINIA	578	149	6	10	385	5	23	472	94	12	0
WISCONSIN	562	84	101	195	132	14	36	326	197	36	3
WYOMING	85	9	0	2	70	1	3	52	29	4	0
GUAM	1	0	0	0	1	0	0	1	0	0	0
PUERTO RICO	82	25	5	47	1	0	4	6	66	9	1
VIRGIN ISLANDS	1	1	0	0	0	0	0	0	1	0	0
Total	21,065	2,723	2,575	3,287	10,153	795	1,532	11,852	7,291	1,718	204

*Data insufficient to classify further.

- Secondary treatment plants use biological degradation to treat the output from primary treatment. Secondary treatment normally removes 65 to 98 percent of the BOD_5, yielding effluent concentrations of 10 to 50 mg/l BOD_5. Under the 1972 Act, EPA requires by July 1977 that publicly owned treatment works achieve BOD_5 effluent concentrations of 30 mg/l and at least 85 percent BOD_5 removal.

- Tertiary treatment plants apply various types of additional treatment to the effluent from the secondary system. These additional processes often involve nutrient (nitrogen or phosphorus) removal and can achieve BOD_5 effluent concentrations significantly lower than secondary treatment.

Nationwide, over 75 percent of the municipal treatment facilities practice secondary or higher treatment, although there are wide variations from State to State. In 12 States, 90 percent or more of the facilities practice secondary treatment or higher, while in six States less than half of the facilities meet those standards.

Over the past decade, two trends are significant: more people are being served by municipal treatment plants, and higher levels of waste treatment are being installed. Since 1962, the number of facilities providing secondary treatment or higher increased from 57 percent of all plants to 76 percent. During the same period, the total population served increased 39 percent, while the U.S. population increased only about 15 percent (Table XI-3).

TABLE XI-3

TRENDS IN MUNICIPAL WASTE TREATMENT

Level of treatment	Number of facilities			Population served (millions)		
	1962	1968	1973	1962	1968	1973
None	2,262	1,564	1,532	14.6	10.1	3.2
Primary	2,717	2,435	2,723	42.2	44.1	54.6
Secondary	6,719	10,042	16,015*	61.5	85.6	105.0
Tertiary	0	10	795	0.0	0.3	2.7
Total	11,698	14,051	21,065	118.3	140.1	165.5

*At least 2,600 of these plants meet EPA's new requirements for secondary treatment.

Two data sources were used to assemble this municipal inventory and classify plants by type of treatment:

- *Municipal Waste Inventory.* First published in 1940 by the Public Health Service. EPA currently maintains this inventory on a computer file and updates it frequently in cooperation with the States. The file contains the name and location of nearly every municipal waste treatment facility in the Nation. In addition, data concerning the quantity and quality of effluents are present in the file.

- *Needs Survey.* Performed in 1973 to determine the cost of building new facilities and upgrading existing facilities to meet the requirements of the 1972 Act. The survey was completed by State and local agencies during June-August 1973. It contains technical data describing the level of treatment and nature of the discharge at each plant needing additional funds.

For most facilities, data from both sources were available. EPA determined which source was more accurate and complete for each State. The result for major municipal facilities is shown in Appendix C. In States where Needs Survey data were chosen, the number of major dischargers shown in Appendix C may vary somewhat from the totals shown in Table XI-2.

INDUSTRIAL/COMMERCIAL SOURCES

As of March 1974, EPA had received approximately 24,500 industrial and commercial permit applications. The number of industrial sources by industry group is shown for each State in Appendix D. Some industrial discharges have a much more damaging effect on water quality than others due to their volume, contents, or location. To focus attention on the most critical dischargers, EPA Regions designated approximately 2,800 industrial plants (11 percent of the total) as major dischargers.

Major and minor dischargers can be grouped into 43 industries depending on the principal product made at each plant. Three of these industries–chemicals and allied products, paper and allied products, and electric and gas utilities–contain 47 percent of the major industrial dischargers (Table XI-4). Plants in these industries often discharge very large volumes of waste water containing oxygen consuming wastes, harmful chemicals, or heat.

Major industrial dischargers are inventoried in Appendix E. Included for every discharger is the company name, principal product, waterbody receiving the discharge, volume of water discharged, and amount of waste discharged for five specific pollutants (BOD_5, nitrogen, phosphorus, total solids, and metals). Data for this inventory came from the NPDES, including applications filed during 1970-72 under the Refuse Act Permit Program (RAPP) and applications filed in 1973 under the 1972 Act. Under the 1899 Refuse Act, EPA and the U.S. Army Corps of Engineers required that all industrial point sources obtain discharge permits. Approximately 20,000 industries submitted permit applications; they currently comprise the bulk of EPA's industrial effluent data base. The RAPP has been replaced by the NPDES program.

The 1972 Act expanded the permit system to include a wider range of pollution sources, including municipal and agricultural dischargers. Approximately 55,000 additional permit applications are expected under this program; most, however, are not yet in EPA's computer system and so are not specifically included in this inventory.

Permits will be written for all industrial point source dischargers, using effluent guidelines that require installation by 1977 of the best practicable control technology currently available to treat the wastes from each specific industry. In areas where water quality requires more stringent treatment, the permit will reflect the stricter water quality standards.

AGRICULTURAL SOURCES

Approximately 6,500 permit applications from agricultural point sources are expected under the NPDES program. Most agricultural operations will be exempt from NPDES because their discharges are generally dispersed and not considered point sources; large feedlots, return flows from irrigated fields, and fish hatcheries are required to have permits. Most of these sources are located in the Midwest and West. By February 1974, the bulk of agricultural permit applications had been received by EPA Regions V, VI, VII, VIII and X (Table XI-5).

FEDERAL FACILITIES

Section 313 of the 1972 Act requires that Federal facilities meet the same pollution abatement standards as other facilities unless specifically exempted by the President. Approximately 7,500 Federal facilities discharge waste water with an impact significant enough to have come to EPA's attention since 1960. Some permit applications from Federal facilities are interspersed among the 38,000 industrial, municipal, and agricultural permit applications received to date. Until all permit applications have been processed, the total number of Federal dischargers can only be estimated.

TABLE XI-4

INDUSTRIAL DISCHARGES BY INDUSTRY GROUP

Industry	Number of surface water dischargers		
	Major	Minor	Total
Agriculture — crops	2	32	34
Agriculture — livestock	4	26	30
Agriculture — other	19	347	366
Metal mining	45	396	441
Coal mining	44	1,154	1,198
Oil and gas mining	28	1,226	1,254
Nonmetallic mineral mining	62	1,034	1,096
Meat products	54	299	353
Dairy products	11	349	360
Preserved fruits and vegetables	50	330	380
Grain mill and bakery products	16	118	134
Sugar and confectionary products	78	61	139
Seafood products	39	598	638
Miscellaneous food and beverages	57	377	434
Textiles	151	458	608
Lumber and wood products	31	477	508
Paper and allied products	407	255	662
Printing and publishing	0	50	50
Chemicals and allied products	522	821	1,343
Petroleum and coal products	136	279	415
Rubber and miscellaneous plastics	15	380	395
Leather and leather products	29	26	55
Stone, clay, and glass products	71	1,041	1,112
Iron and steel	142	281	423
Nonferrous	66	247	313
Miscellaneous primary metal products	4	41	45
Fabricated metal products	149	742	891
Electric and nonelectric machinery	39	675	714
Transportation equipment	49	277	326
Other manufacturing	6	192	198
Railroad transportation	9	355	364
Other land transportation	0	132	132
Water transportation	0	102	102
Air transportation	3	30	33
Miscellaneous transportation	3	46	49
Communication	0	9	9
Electric and gas utilities	392	2,397	2,789
Water and sanitary services	22	1,504	1,526
Wholesale and retail trade	4	1,166	1,170
Finance, insurance, and real estate	0	309	309
Other services	1	1,069	1,070
Government	24	616	640
Nonclassifiable	17	1,344	1,361
Total	2,801	21,668	24,469

The Federal Government controls nearly 36 percent of the Nation's land area including over 21,000 Federal installations. Many of these installations contain multiple facilities; for instance, one National Forest installation may have 50 or more developed campsite facilities that generate wastes.

An inventory of important Federal facilities appears in Appendix F. The bulk of these facilites are in Department of Defense, Department of Interior, and Department of Agriculture installations. These data were compiled by EPA from information based on abatement needs reported by Federal agencies. A system is under development that will eventually contain data about the quality and quantity of effluent discharges from Federal facilities, comparable to the data for dischargers in the non-Federal sector.

TABLE XI-5

AGRICULTURAL PERMIT APPLICATIONS RECEIVED*

EPA Region	Feedlots	Irrigation return flow	Fish hatcheries	Other	Total
I	3	1	5	4	13
II	13	0	0	0	13
III	1	0	2	1	4
IV	0	0	0	0	0
V	61	6	80	1	148
VI	224	9	49	0	282
VII	215	1	28	0	244
VIII	248	7	5	0	260
IX	40+	10+	0	0	50
X	109	68	15	0	192
Total	914	102	184	6	1,206

*Does not include States operating permit programs (Connecticut, Michigan, Wisconsin, California, Oregon, Washington).

+Approximate.

PART III

WATER QUALITY GOALS

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XII. 1977-83 GOALS

This part of the report provides a preliminary identification of the Nation's navigable waters that can reasonably be expected to achieve the 1977 and 1983 goals of the Act, to attain levels of quality adequate to provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife, and also allow for recreational activities in and on the water. This part further provides a preliminary identification of those waters cited by the States as major problem areas in their program plans for fiscal year 1974.

DESCRIPTION OF THE PLANNING PROCESS

The data for this part are listed in Appendix G. They are obtained from the continuing planning processes initiated by the States in 1973 under requirements of the Act. These processes consist of:

- A basin planning process, implemented in accordance with requirements of Section 303(e) of the Act.
- A management process for State water pollution control programs under Section 106 of the Act.

Every year, each State develops the following materials and submits them to EPA:

- An assessment of the quality of State waters and a strategy for controlling pollution.
- A designation of basins, and segments of basins, which comprise all State waters.
- A classification of segments based on assessments of the point source controls needed to achieve a level of water quality that will support wildlife and recreation in each segment.

The first preliminary versions of these materials were submitted by the States in 1973. During the next 2 years, the States will direct their planning processes with the end-view of refining and improving their knowledge and understanding of water quality and those measures that must be taken to achieve the goals of the Act. The list of basins and segments presented here gives a general idea of the task ahead.

The planning process requires that the States classify water segments according to two categories: effluent-limited or water-quality-limited. In an effluent-limited segment, the water quality goals of the Act are expected to be achieved by application of required 1977-level effluent limitations. Achievement of water quality goals by 1977, or earlier, may generally be expected in effluent-limited-segments. Exceptions to this include cases where delays may be created by the timing of control activities, such as municipal construction grants, by peculiarly difficult industrial discharge control problems, or by extended periods of litigation.

In water-quality-limited segments, more stringent effluent limitations or nonpoint source controls are needed to meet the goals of the Act. Here, study and planning are needed before allocating waste loads in a generally complex situation. Goals will probably be achieved later than 1977 in these segments.

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RESULTS

The following summary of national water quality conditions is based on two sources: the detailed Segment Gazetteer listing in Appendix G, and the descriptions of major pollution problems in Chapter XIII. The Gazetteer and the descriptions are of a preliminary nature, and are subject to change as water quality monitoring, planning, and program actions proceed. Since not all States have fully approved programs, and not all aspects of water quality conditions can be detailed in any State program, the national summary statistics presented here may understate the extent of many pollution conditions.

A total of 3,313 segments have been identified. This figure includes all segments specifically listed by the States, plus an artificial segment for each basin where segments were not specifically listed. In all, 564 basins have been identified. Since some States have not yet provided a list of basins or segments, the total number of segments listed here is understated. The numbers of segments identified by the States are:

●	Effluent-limited segments	1,546
●	Water-quality-limited segments	1,609
●	Not classified	158

Effluent-limited segments, although fewer in number, probably cover substantially more miles than water-quality-limited segments. This is due to the fact that water-quality-limited segments are ofetn smaller in area and stream distance than effluent-limited segments, and because some States have lumped all nonwater-quality-limited waters into one effluent-limited segment.

Experience with issuing and enforcing permits and from preparing basin plans, may lead to reclassification of effluent-limited and water-quality-limited-segments. In addition, the number of segments classified will expand as the planning and permitting processes proceed.

This tally of segments will change as planning progresses, and as all States submit complete lists of basins and segments. Experience with issuing and enforcing permits and from preparing basin plans may lead to reclassification of effluent-limited and water-quality-limited segments. In addition, the number of segments classified will expand as the planning and permitting processes proceed.

Information available from some States when this report was prepared did not allow for projecting the dates by which waters are expected to meet the high levels of quality required by the Act. In the Segment Gazetteer, we have projected the date expected when the water quality goal will be achieved by applying the following criteria:

- For waters that currently support wildlife or recreation uses, the reach is designated as ***WQS (Water Quality Standards) being met.***
- If wildlife and recreation uses are precluded by natural conditions, the reach is designated as ***WQS exception required.***
- For effluent-limited-segments where no specific delaying factors are cited, the reach is designated as *1977.*
- 1983 - For effluent-limited-segments where delaying factors are cited, and also for water-quality-limited-segments where correction of nonpoint sources is not said to be required, the reach is designated as *1983.*
- For water-quality-limited segments where correction of nonpoint sources is said to be required, the reach is designated as ***after 1983.***

In areas where States have not completed classification of segments, we have used notes or dates based on program narratives when available. Projections for 75 entire basins were derived from the State Program Plans. Two

States made generalized projections for the entire State, which prevented using separate segment dates, while two other States provided no basin-segment list, but gave a statewide assessment.

Of the segments for which dates could be individually determined, 1,343 are projected to achieve national water quality goals by 1977, 1,155 after 1977 but by 1983, and 107 after 1983. In addition, 14 basins without segment data are projected to achieve goals between 1977 and 1983, and 47 after 1983. Two States as a whole are projected to achieve goals between 1977 and 1983, and two after 1983.

Only four segments were indicated to have natural conditions that prohibit meeting the highest water quality goals. Fourteen States cited nonpoint sources as major contributors to water quality problems, including 53 segments, 30 entire basins, and one whole State. Six States have indicated that water pollution problems in another State affect their ability to attain water quality goals in major problem areas.

XIII. STATE PROBLEM ASSESSMENTS

This chapter consists of water quality problem assessments prepared by each State in cooperation with EPA Regional Offices. These assessments are the most up-to-date overview available of the Nation's water pollution problems as seen by the States, with the exception of three States and territories that have not contributed to this report. The assessments were originally provided as part of the States' fiscal year 1974 program submissions for funding under Section 106 of the 1972 Act. Subsequently, revisions to the original assessments were received at midyear.

ALABAMA

The State has generally good water quality. There are, however, areas with complex water quality problems. Jefferson County and the Tuscaloosa area have large volumes of wastes being discharged into intermittent streams and reservoirs. This problem is being compounded by interbasin transfers of supply water in Jefferson County, which further decreases flows in many of the streams in the Birmingham area. The third problem area is Mobile and Mobile Bay. The Bay supports a highly sensitive shellfish industry that is threatened by increasing pollution levels.

ALASKA

In general most of the waters in the State of Alaska are in their natural conditions unaffected by man. Because of this, the key activities in water quality control in this State are preventive in nature rather than abatement oriented. There are some areas in the State, however, where man's activities have affected adversely the qualities of waters. In general, these can be described as effects primarily from a few industries, with lesser effects resulting from municipalities. The State has enacted a permit program for industrial waste dischargers and a program for providing construction grants for municipalities. Alaska's construction grant program has resulted in the completion of sewerage systems and sewage treatment plants in municipalities that previously discharged raw or inadequately treated wastes into the receiving waters.

The middle Tanana River and the lower portion of the Chen River have been affected adversely by the discharge of municipal wastes from the Fairbanks metropolitan area. Planning for a new sewage treatment facility has been completed, and the facility is now under construction.

The marine waters of Women's Bay and Saint Paul's Harbor at Kodiak have been affected adversely by large amounts of seafood processing wastes. The majority of the processors have initiated abatement action through the use of treatment techniques, and a corporation has recently begun manufacturing a useful product from the wastes previously discarded in the bay.

A pulp company that discharged wastes into Ward Cove and adversely affected the marine environment was under State permit to abate the problems that exist.

Another lumber and pulp company which has been discharging wastes into Silver Bay for many years, adversely affecting the marine environment there, is now under a State permit, and is actively engaged in providing facilities that will abate the existing problem.

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AMERICAN SAMOA

American Samoa has a wide variety of pollution problems, some of which are seldom found elsewhere.

An estimated 50 percent of the Island's pollution problems comes from over-developed septic tank fields and untreated domestic waste. With very little land available for waste disposal, most waste is dumped into offshore waters. These considerations, when aggrevated by inadequate treatment of municipal and industrial wastes, vessel waste discharges, and nonpoint source contributions, are creating pollution problems in the lagoons, harbors, and offshore waters of the islands.

ARIZONA

Salinity (total dissolved solids) is the most serious water quality problem in the Lower Colorado Basin. The Colorado River system in Arizona carries a large salt burden (dissolved solids) contributed by a variety of natural and man-made sources. Depletion of streamflow by natural evapotranspiration and by consumptive use of water for municipal, industrial, and agricultural uses reduces the volume of water available for dilution of this salt burden. As a result, salinity concentration in the Lower Colorado River system exceeds desirable levels and is approaching critical levels for some water uses.

All of the water resources in the State are allocated. Approximately 94 percent of the surface water withdrawn is used for irrigation. The irrigation water returning to a surface source generally shows an increase in nutrients, temperature, salts, and sediments.

Arizona faces somewhat more difficult problems than most States because of its arid climate. Except for the Colorado River, when flow is regulated, all perennial bodies of water in Arizona are subject to wide variations in stream flow. This natural variation makes it very difficult to identify any actual or potential pollution problem.

Potential problem areas include (1) eutrophication of mountain lakes, (2) pollution of ephemeral bodies of water and (3) introduction of wastewaters into the subsurface aquifer.

ARKANSAS

Inland Surface Waters

Where water quality is not in compliance with water quality standards, the problems are localized and an entire segment or basin is not totally affected. There are a number of municipalities within the State which have waste treatment inadequacies. These inadequacies result from overloaded facilities, insufficient degrees of treatment, and a lack of pretreatment by industries hooked into municipal systems.

Continued development around Arkansas' recreational lakes and streams without adequate controls presents future problems. Uncontrolled development with utilization of septic tanks is defintely causing localized concern and potential eutrophication problems.

Nonpoint source pollution affects greater than 50 percent of the land area of Arkansas. Accurate assessment needs to be made in the Ouachitia and Red River Basins for wastes associated with oil production. It is known that there are evaporation pits for brines that discharge to surface streams, especially during periods of flooding. In other areas, runoff from agricultural and silvicultural activities contributes pollutants such as nutrients, pesticides, organics, and silt. The Arkansas River Valley around the Russellville, Dardavelle, Clarksville area is being strip mined, and those activities will possibly increase in years to come unless controls are implemented.

Groundwaters

Arkansas is a major user of groundwater both for domestic and other uses. With the increasing use of groundwater for irrigation purpose, some areas of the State have had groundwater levels decline, with the danger that shallow aquifers are subject to pollution to a greater extent than in past years.

In oil production areas of the State, injection wells have been utilized for disposal of brines from oil recovery operations. In these areas, a potential exists for contamination of freshwater aquifers. Sanitary landfill seepage poses another potential for contamination of freshwater aquifers as well as surface waters.

CALIFORNIA

The State's most difficult water quality problems are the Sacramento, San Joaquin, and Santa Ana Rivers. The Sacramento has a high nonpoint source problem stemming mainly from agriculture and specifically related to high nutrient concentrations. The San Joaquin also has a nonpoint source problem from nutrients resulting from intensive agricultural activity. The Santa Ana River, like the others, receives heavy nonpoint contributions from agriculture and also from poor quality groundwater inflow.

Other surface water problems include Little Grizzly, Spring, and Leviathin Creeks, which are severely polluted by mine drainage, causing low pH levels and heavy metals problems. The State's north coastal streams are degraded by heavy siltation and sedimentation due in part to the geology of the region, logging, and road construction.

The inland waters which present the greatest problems are Clear Lake (Northern California) and the Salton Sea (Southern Desert Area). Clear Lake is in the latter stages of eutrophication, inhibiting its recreational use. Algae growths continue to cause problems, the source being nutrients from bottom sediments that are recycled naturally. The Salton Sea has a major problem with evaporation, which increases salt concentrations and so threatens recreation and fish habitats.

California's groundwaters have experienced widespread degradation. The most extreme examples are the Santa Ana Basin, Imperial Valley, portions of the San Joaquin Valley, and Tulare Lake Basin. The situation is primarily caused by percolation of salt-laden agricultural water.

COLORADO

Colorado Basin

The crucial segments within the Colorado basin are those with high water quality which are threatened by degradation from increased development and rapidly expanding recreational activities. The three lakes area (Grand Lake, Lake Granby, Shadow Mountain Reservoir) lying adjacent to Rocky Mountain National Park are adversely affected by tourist trade and increasing resident population. The Fraser and Roaring Fork Rivers suffer from intense population pressures, as well as continuous recreational activities. The Eagle and Blue Rivers receive wastes from burgeoning recreational areas. In the Colorado River, salinity is a major problem that is multiplied by downstream uses and nonpoint sources.

Unlike the above segments, the San Miguel River is badly polluted by point and nonpoint sources. The State does not expect this segment to meet acceptable water quality standards after best practicable technology is applied.

South Platte Basin

The South Platte River from its source to the Chatfield Dam has high water quality but risks degradation due to many kinds of recreational pressures. The State views this segment as a high priority area. In terms of existing problems, this area is the most crucial. Its major sources of pollution are industrial and municipal point sources, irrigation return flows, and feedlot operations.

Green River Basin

The Yampa River in the Green River Basin is isolated as a segment which currently maintains high quality water but is threatened by increased development. The skiing industry, coal mining, and oil shale development will cause degradation if not properly checked.

Arkansas River Basin

The Arkansas River main stem and Fountain Creek will not meet water quality standards after best practicable technology is employed due to an abundance of high natural sources, agricultural return flows, and point source contributions.

CONNECTICUT

Achievement of best practicable treatment at essentially all point sources should result in the achievement of water quality standards in most of the State. However, certain stream systems have been identified which warrant detailed analysis related to the need for pollution abatement measures beyond best practicable treatment to achieve higher use standards. Approximately 26 stream segments in this category have been identified with possible water quality problems such as excessive organic waste loadings, combined sewer discharges, and eutrophication.

DELAWARE

Christina River

Water quality is generally good in the upper segment, but the lower segment is subject to degradation by the tidal influence of the Delaware River.

Indian River

A large, substantially unsewered area south of the Indian River main stem is causing high bacterial counts. This area has received a grant offer from EPA.

Blackbird

Algae problems are present in Silver Lake from effluent discharged from Middletown sewage treatment plant on the lake. The algae problems may not be resolved by construction of the force main from Middletown to Adessa. The shallow ponds are also fed by farm runoff, and algae problems may persist.

Little Assawoman

Overflowing septic systems in Fenwick Island, as well as a poorly operated package treatment plant, have degraded water quality in this area. The State has taken legal action against the developer, and the plant is being modified.

White Clay

There have been bacterial problems in this segment resulting from wet weather sewer overflows. Also, there have been recurring water quality violations of the zinc and phenol standards. The phenol violations are confined to the Red Clay Creek. The zinc is point-source related; the phenol cannot be explained but apparently is due to an out-of-State source.

Brandywine

This segment has been experiencing bacterial counts in excess of standards as a result of urban runoff problems.

DISTRICT OF COLUMBIA

All waterways in the District are subject to high levels of fecal coliforms and sediment loads. The high coliform levels are apparently being caused by sewage treatment plant overloads and malfunctions, combined sewer overflows, and storm water discharges. The high sediment loads are due to upstream development which is outside the District and hence beyond its control.

FLORIDA

St. Mary's River Basin and Coastal Area

This subbasin has a low orthophosphate level, the pH is acidic, and there is a high color factor. There are bacteriological problems in Harrison and Alligator Creeks. Heavy industrial wastes near Fernandina Beach have caused significant contamination.

Coastal Area Between St. Mary's River and St. John's River

There are bacteriological problems in Mill's and Thomas' Creek. Amelia River Estuary has high organic industrial wastes and heavy bacterial pollution, resulting in the closure of shellfish areas.

St. John's River Above Oklawaha River

The upper reaches of the river to the confluence with the Econlockhatchee River are high in nutrients due to swamp and marsh drainage and agricultural runoff. The middle reaches of the St. John's River from Econlockhatchee River to Wekiua River confluence receive tremendous loads from domestic waste sources. Algae and weed problems are common, with occasional fish kills and high turbidity. Lakes in these regions are in advanced eutrophic condition.

Oklawaha River

Heavy pressure from agricultural, urban, domestic, and industrial effluents has affected water quality in the river. There are advanced stages of eutrophication in the river's upper reaches.

Withlacoochee River

Swift Creek exhibits turbidity, fluorides, phosphates, and bacterial problems from mining and industrial sources. There are nutrient problems in the Withlacoochee River, and an industrial source is causing potential turbidity problems in Hunter's Creek.

Santa Fe River

Potential nutrient and bacterial problems in the river and some lakes and creeks are of concern to the State. The problems are principally the result of malfunctioning sewage treatment plants and septic tank effluent.

Coastal Area Between Myakka River and Alafia River

The Manatee River (State Road 60 extended to Tampa Bay) shows current bacteriological problems. Potential bacteriological problems exist in North Sarasota Bay and Coastal Sarasota County. Tampa Bay and Bishop Harbor have nutrient buildups, while Palm Sola Bay and Braden River have possible bacteriological problems.

Hillsborough River Basin and Coastal Area North of Alafia River

Hillsborough Bay has nutrient problems from domestic and industrial sources as well as surface drainage. Hillsborough River, McKay Bay, Delavey Creek, Mill Creek, Pemberton Creek, Lake Thonotossassa, and Palm River exhibit nutrient and bacteriological problems.

Coastal Area Between Hillsborough River and Withlacoochee River

There are nutrient and bacteriological problems in Old Tampa Bay, Pithlachascottee River, Mobbly Bay, Rocky Creek, Boca Ciega Bay, Tarpon Springs, Salt Lake, Clearwater Bay, and the Mouth of Anclote River. The problems are caused by domestic and agricultural sources.

Kissimmee River

Nutrient problems exist from domestic and agricultural sources on Shingle Creek, Lake Tohopekaliga, Lake Kissimmee, the Upper Kissimmee River, Okeechobee, and the canals in highlands and Glades counties.

Coastal Area Between St. Johns River and Turkey Creek

Domestic effluent and urban runoff are high throughout the subbasin. There are nutrient and bacteriological problems in the Halifax River, and bacteriological problems in the Guano River. Certain shellfish areas are closed.

Turkey Creek and Coastal Area South to St. Lucie River

Nutrient problems from domestic effluent and urban runoff near populated areas have forced closing of some shellfish areas.

St. Lucie, Martin, and Palm Beach Counties

Agricultural and urban runoff and domestic effluents cause problems with nutrients and bacteria in the coastal areas. Lake Okeechobee has potential eutrophication problems primarily from agricultural runoff. St. Lucie River (and North and South Forks), Lake Worth Basin, and West Palm Beach canal have nutrient and bacteriological problems.

Lee, Hendry, and parts of Glades and Charlotte County

Caloosahatchee River, Estero Bay, and adjoining waters have bacteriological problems from domestic effluents. Nutrients from domestic effluents, nutrients from agricultural runoff, and thermal effluent cause problems in Orange River. Shellfish areas are closed. The subbasin will meet standards by 1983.

Broward and Collier Counties

Naples Bay and Dollar Bay have bacteriological problems from domestic effluents. Shellfish areas have closed except for extreme southern portion of Collier County (south of Gullivan Bay). There are nutrient and bacteriological problems in the coastal areas of Broward County. Canals in the interior portion are experiencing problems with bacteria and nutrients. Broward County will probably violate standards intermittently due to urban runoff.

Dade and Monroe Counties

Conservation Area 3 has potential for nutrient problems from agricultural runoff. The east part of Dade County and Florida Keys (especially southwest end of Keys) experience bacteriological and nutrient problems from domestic effluent and urban runoff.

Apalachicola River

There are potential bacteriological problems and turbidity problems. The area within 2 miles of the river mouth is closed for shellfish harvesting due to bacteriological counts.

Coastal Areas between Apalachicola River and Choctawhatchee River

St. Andrews and North Bay (partial) are closed for shellfish harvesting due to bacteriological loadings. There are nutrient loadings from domestic and industrial sources and urban runoff.

Escambia River

Domestic and industrial effluents are causing problems with nutrients and certain other parameters such as toxicity, color, and temperature in Escambia River. (Some effluents come from bordering State.) Escambia Bay is experiencing serious problems with high nutrients and low dissolved oxygen from domestic and industrial effluents. Numerous fish kills have been reported.

GEORGIA

There are several thousand miles of streams in Georgia; however, about 600 miles are included in the reaches where water quality problems exist and water quality standards are being violated. Those reaches are basically downstream of discharges from publicly owned sewerage systems. As the construction grants program becomes fully implemented by EPA and the State with local governments, existing violations of water quality standards will be reduced.

Georgia is unique in the type of streams that flow through the State. The northern portion consists of the foothills of the Appalachian Mountains, with hundreds of small mountain brooks with cool, clear waters that support native trout. On the Piedmont Plateau, there are a number of streams with minimum flows in the range of 1,000 cfs to 3,000 cfs. The Coastal Plain has the Oketenokee Swamp and several streams from which "black water," frequently low in pH and DO, flows into the estuarine zone.

There is no major stream in Georgia grossly polluted for its entire length. Grossly polluted conditions exist only in a few cases such as the Chattahoochee immediately downstream of Atlanta, the Conasauga River downstream of Dalton, the Flint River downstream of Atlanta, and the South River downstream of Atlanta.

GUAM

No water quality assessment available.

HAWAII

The State has no major river systems or lakes, so the basic water quality problem is focused on the coastal waters. The major sources of coastal water pollution are nonpoint discharges, including irrigation tailwaters carrying silt and chemicals, cesspool seepage, sediment from erosion, and storm runoff. Another problem which Hawaii faces is the discharge of oil and sewage from large vessels.

The Island of Oahu has the most serious pollution problem of any of the five islands; 80 percent of the population of Hawaii is located in Honolulu on Oahu, and the major industrial development is concentrated there also.

IDAHO

The number one priority in the State of Idaho is the Upper Snake River Basin. The largest concentration of major industries and agriculture is located in this basin. In addition, the basin has the largest area and the second largest population. Therefore, the water pollution problems are worse in this basin. The most serious problems are in the American Falls-Milner Dam segment.

The Southwest Idaho basin is second in order of priority. This basin is the second largest in area and has the greater total population and population density. There is also a large concentration of industrial and agricultural use in this basin, which has contributed heavily to water pollution problems in the Snake, Boise, and Payette Rivers.

The panhandle Basin is third in order of priority. The major activities which contribute to water quality problems are mining and logging operations. The South Fork of the Coeur d'Alene is the most serious problem in this basin, primarily the result of mining operation on the South Fork.

The other three basins in the State of nearly equal priority are the Bear Basin, Clearwater Basin, and the Salmon Basin. These basins have smaller populations and lower levels of agricultural and industrial activity as compared to the higher priority basins.

ILLINOIS

The main stem of the Illinois River is the State's most critical pollution problem. This segment was highlighted by the State because it presents complex waste-load water use interrelationships. The upper reaches of the river are affected by effluents from Chicago, as well as discharges of heated effluents from electric power plants and industrial sources. In addition, the Illinois receives effluent from industries and municipalities downstream, and is also affected by high nutrient and algae concentrations discharged by the Fox River. Finally, the City of Peoria uses the river for water supply and also discharges significant waste loads.

Nonpoint source problems in Illinois are caused primarily by coal mining and agricultural runoff. The problem areas caused by coal mining are mostly in southern Illinois in the Big Muddy, Wabash, Ohio, and Kaskaskia River Basins. The worst problem areas caused by agricultural runoff are in the central part of the State.

INDIANA

Collection and treatment of domestic sewage are, administratively, the single most significant pollution problem in the State. The problem relates to overloaded municipal treatment plants and the need for advanced waste treatment for communities with inadequate stream flow.

The State's main industrial problems are currently concentrated in the Lake County area where sizeable steel mills and oil refining operations are prevalent. Other troublesome industries include food processing and automotive support. Abandoned coal mines are a major problem for southwestern Indiana.

The Wabash River Basin experiences serious pollution problems on occasion caused by oil field operations; 85 percent of the oil wells in Indiana are located in the lower Wabash, while the remaining 15 percent are in the upper Wabash.

IOWA

Soil erosion is considered a major contributor to water quality degradation, adding significant amounts of silt, organic matter, nutrients, and pesticides to the State's waters. Violations of existing ammonia and dissolved oxygen standards are occurring in several small interior streams as a result of municipal, industrial, and agricultural discharges.

There are approximately 500 communities that are not served by central sewer systems. Communities served by sewers may still have problems from a lack of proper plant operation and maintenance, the use of combined sewers, and excessive infiltration.

In addition, the State is presently experiencing a growth of residential and recreational developments in previously rural areas, particularly around impoundments that have an attraction because of their water recreation value. Since political subdivisions capable of providing adequate sewerage service do not exist in these areas, these developments may cause serious waste disposal problems in the future.

Other existing or potential sources of water pollution include failure of individual disposal systems, several thousand confined livestock feeding operations, and the presence of solid waste disposal sites on flood plains.

KANSAS

Water quality problems resulting from nonpoint runoff are attributed to two basic causes: 1) agricultural (other than feedlots and surface runoff), and 2) mineral problems related to outcroppings of geological formations. Agricultural runoff is a problem in every basin, with quantities of nutrients, organics, and bacteria entering the waterways from Colorado. Nonregulated streams entering are heavily laden with sulfates and chlorides resulting from irrigation. Geological formations contribute to mineral pollution of streams located in a band 50 to 75 miles wide spanning the central portion of the State.

Severe water quality problems occur in Kansas, Missouri, and Arkansas River Basins. These river basins experience their worst water quality during period of high flow and runoff, with high nutrient levels and bacteria counts, increased BOD_5 concentrations, and low levels of dissolved oxygen. At low flow, the main problem is inadequately treated municipal waste discharges.

Some local problems are caused by unsewered communities. Isolated industrial discharges cause water quality problems at specific discharge points throughout the State.

Confined livestock feeding operations are spread throughout the State and particularly concentrated in the western portion. These operations increase bacteria and BOD_5 loadings throughout the basin.

KENTUCKY

No water quality assessment available.

LOUISIANA

Calcasieu River Below Oakdale

This segment presents the State with its most acute pollution problem. The major symptoms are oxygen depletion, high bacteria counts, and coke and oil deposits caused by heavy concentrations of industries and population. The waters in this segment are used extensively for primary and secondary contact sports as well as shellfish propagation.

Mississippi River from Huey Long Bridge to Head of Passes

Heavy concentrations of industry discharging taste and odor compounds, a large number of municipal discharges raising the coliform bacteria count, and sewage discharged from maritime activities associated with the Port of New Orleans combine to adversely affect shellfish propagation in the segment.

Ouachita River from Arkansas Line to Columbia Lock

The principal problems in this segment are oxygen depletion from municipal and industrial discharges and high bacteria counts. Degradation of water quality is significant in that water is used as secondary source of water supply and for primary contact water sports.

Lake Pontchartrain

The major pollution problem is caused by high coliform bacteria counts originating from polluted storm water pumped along the lake, municipal discharges, and fishing camps.

Bayou Bienvenue

High incidences of coliform bacteria cause potential harm to the oyster-growing waters nearby. Bacteria originate from contaminated storm water, inadequately treated sewage, and discharges from ships in New Orleans Harbor.

Mississippi River from Old River Control Structure to Huey Long Bridge

Heavy concentrations of petroleum refining and petrochemical industries cause taste and odor problems. The water is used for public water supply, thus creating a dangerous situation.

Terrebone Estuarine Area

Bacterial concentrations originating from unsewered residences and bypass of storm water, as well as oxygen depletion, are the basic problems in this segment. Unstable soils, low land elevation, and a high groundwater table make solving the problems complicated and costly.

Vermillion River

Little or no dependable dilution flowing from the river, coupled with heavy concentrations of municipal and industrial discharges, cause considerable oxygen depletion and severe pollution conditions.

MAINE

Maine has a significant problem with maintaining high water quality in its lakes. Most of the State's Great Ponds are classified high water quality, but run the risk of aging, either naturally or culturally, because of unwise land and water resource utilization. Maine developed a classification for lakes and other impoundments called "Lake Stress Quality" (LSQ), denoting that an impoundment may not be presently in violation of its assigned standard, but is in such a trophic state that some or all normal uses are impaired. Some lakes are culturally stressed and are actually known to have water quality standard violations and are therefore water quality classified. They are: Annabessacook, Estes, Haley and Sebasticook.

MARYLAND

Washington Metropolitan

This subbasin is highly urbanized, and water quality problems mostly stem from municipal wastes, a portion of which come by way of overflowing interceptors and storm sewers. Silt from land development is also a major problem. These pollution sources cause the Potomac River below Washington to have severely depleted oxygen content and excessive algae blooms. The State has decided that the best approach to control pollution in this subbasin is through the imposition of waste load allocations in a joint effort with Virginia, the District of Columbia, and the Federal Government.

Patapsco River

The lower Patapsco River and Baltimore Harbor are severely polluted; the waters are unsuitable for most uses. The main sources of pollution to Baltimore Harbor are urban runoff, industrial discharges, waste from commercial shipping, Baltimore City Patapsco Sewage Treatment Plant, mosquito control agents, and agricultural operations. Pollution sources to other parts of the subbasin—including urban runoff, sewer overflows, industrial wastes, and benthic demands from an accumulation of wastes—severely degrade water quality.

The Back River has poor water quality in the upper portion. The condition is evidenced by eutrophication due to nutrient content from a major sewage treatment plant and from urban runoff.

North Branch Potomac

This subbasin is degraded throughout its entire length, mostly from acid mine wastes emanating from 70 active coal mines and 1,500 abandoned mines.

Patuxent River

Encroaching urban sprawl threatens to destroy water quality from the Laurel - Savage Area downstream, where dissolved oxygen and bacterial standards are not now being met. The primary source of poor water quality is eight major treatment plants discharging wastes that lower dissolved oxygen and add nutrients. In the upper Patuxent watershed, urban and agricultural runoff have raised the bacterial density above the acceptable standard. This part of the watershed also has turbidity and siltation problems caused by construction and subsequent land erosion.

Coastal Area

Because of the fragile coastal ecology, the State sees this subbasin as a priority area. Bacterial pollution from food processing, treatment plants, and agricultural runoff cause most of the problems. Wastes from recreational areas along the ocean front present an imminent problem.

Pocomoke River

The Pocomoke is a slow-moving stream subject to tidal action. High bacterial levels have closed 316 acres of water to shellfish harvest. The major pollution sources include municipal wastes, agricultural runoff, and food-processing plants.

Elk River

The State believes that in this subbasin nonpoint contributions, which might not be controllable, could be as significant as point source contributions. Algae growths have been the direct result of waste discharges from municipal treatment plants and runoff-related sources.

MASSACHUSETTS

A wide range of conditions affect various parts of the State. Almost every basin has its serious water quality problems. In analyzing the problems, it is apparent that, with few exceptions, the severest pollution results from the discharge of untreated or inadequately treated municipal wastes. Sources of pollution from industries are most frequently secondary sources, which have less total impact on the respective river basins.

MICHIGAN

Inland Streams

Michigan estimates its useable stream length in excess of 35,000 miles. The exact mileage not meeting water quality standards cannot be determined because of seasonal fluctuations, lack of definitive standards, and economic limitations on monitoring programs. However, with the data available, we estimate less than 3 percent of Michigan's streams would be in consistent violation of present standards. Michigan's streams not meeting standards are generally those reaches below the major population centers; problems are largely caused by municipal sources or a combination of municipal and industrial sources. Michigan has identified 57 such stream reaches which are currently known or suspected problem reaches and require intensive surveys. Sixteen of these have been identified as water quality segments.

Inland Lakes

Michigan has about 11,000 inland lakes, totaling over 750,000 surface acres. This resource, however, is being subjected to continuing attrition resulting from eutrophication by natural and man-made causes. The trophic state of all lakes in the State has never been determined. However, Michigan estimates that approximately 18 percent are eutrophic from mainly natural causes, approximately 32 percent are eutrophic or experiencing problems of over-fertilization from unnatural sources, and approximately 50 percent are not experiencing problems associated with eutrophication. Definitive data to support these estimates are not currently available. We feel, however, that this is a widespread problem and is not susceptible to public recognition until an advance stage of eutrophication causes practically incurable nuisance conditions. Special problems are the lakes found at the mouths of several of the major tributaries to Lake Michigan. These lakes receive significant discharges from industrial and municipal sources, in addition to buffering the tributary load prior to entry to Lake Michigan. There are only 10 lakes and 26 reservoirs that now receive point source discharges. All of these will have phosphorus removal facilities by 1974.

Great Lakes

Michigan borders four of the five Great Lakes and has over 2,500 miles of mainland Great Lakes shoreline. There are relatively few direct discharges to the Michigan portion of the Great Lakes; however, we have considered the connecting channels of the Detroit River, St. Clair River, and St. Marys River as part of the Great Lakes system. The principal problem historically has been, and is, the impact of the population and industrial base of Southeastern Michigan and the Detroit area on the Detroit River and on Lake Erie. One result has been excessive fertilization of portions of Lake Erie and subsequent undesirable changes in its aquatic ecosystem and other quality indicators. Control programs for Detroit area municipalities and industries initiated in 1965 have reversed this trend and, if the programs continue on schedule, Michigan will not rank this problem as high in priority as in the past.

The principal bays of the Great Lakes, especially Saginaw Bay and Green Bay, are identified problem areas. These bays are hydrologically isolated from the main lakes and thus react faster to environmental stresses than the main lakes. Green Bay, including Big and Little Bay DeNoc, currently has taste and odor problems that interfere with public water supplies. Saginaw Bay has excess dissolved solids and nutrients and has experienced periodic taste and odor problems in public water supplies. The problems in the bays are caused by sources in the tributaries and also by their physical structure, the bays being relatively shallow and having little water exchange with the main lakes.

The St. Clair River and Lake St. Clair have continuing problems associated with past discharges of mercury to the St. Clair River. This problem is not evident in the chemical quality of the water but, through biomagnification, it is a problem in the sport fishes. There is also a problem of elevated levels of chlorinated hydrocarbons such as DDT and PCB's in the fish, resulting in restrictions on the sale of fish from Lake Michigan (due to PCB's and DDT) and Saginaw Bay (due to PCB's).

Groundwater

The total size of Michigan's groundwater resource is not known. However, some problem areas have been identified.

There are few deep well disposal sites for industrial waste disposal in the State. The formations containing sites are monitored, and in addition are isolated from usable groundwater formations. None of these have caused problems in the groundwaters. There are, however, problems of brine contamination in groundwater aquifers in some areas from natural sources, improper disposal practices in oil fields several decades ago, and abandoned wells which were not properly plugged. In addition, there are isolated areas where groundwater contamination has resulted from spills or leaks of petroleum products, improper disposal of industrial wastes in landfills or lagoons, and drainage from improperly stored road salt. In general, groundwater problems cover small areas and are isolated in the State. Our knowledge in this area is increasing as extensive evaluations are being made to assess the effects of proposed land disposal projects.

MINNESOTA

St. Louis Segment (Lake Superior Basin)

This segment is in violation of the total group coliform and color standards. The major sources of the violations are a large cluster of industrial dischargers, dominated by iron mining companies and municipal dischargers.

Cottonwood River Segment (Minnesota River Basin)

A heavy nonpoint source contribution plus discharges from 11 municipalities causes this segment to be in violation of the total group coliform, total suspended solids, and turbidity standards.

Des Moines River Segment

This segment is in violation of total group coliform, suspended solids, and turbidity standards due to heavy nonpoint source contributions and several municipal discharges. The Minnesota River, Mississippi River Segment, Red River (North Segment), and Zumbro River are all in violation of coliform and turbidity standards due to heavy municipal and industrial discharges.

MISSISSIPPI

The State has many areas of poor water quality as evidenced by the more than 90 water quality segments across the State. Most of these segments should not present any unusual problems due to the fact that most of the pollution is originating from municipal and industrial point sources. There are two areas with major nonpoint source pollution—the Mississippi Delta area of the Yazoo River and the Mississippi Sound.

MISSOURI

Water quality problems are numerous in the State. Municipal waste discharges have created problems in receiving streams and rivers. These problems stem from both rural areas and cities and are caused by: lack of adequate enforceable zoning around growing cities, resulting in proliferation of sewage treatment facilities; numerous septic tank systems, resulting in effluent surfacing in streets and roadside ditches or flushing into nearby creeks; and incorrect operation and maintenance of treatment plants.

Uncontrolled or no pretreatment of industrial waste sometimes results in overloaded municipal facilities. This is further complicated by improper or inefficient operation of existing facilities. Meat-processing industries in several Missouri communities are a graphic example of high-strength wastes. Isolated cases of direct industrial waste discharges cause major pollution problems in given basins, resulting in biological growths, bottom deposits, toxic materials, etc. Discharges include: mining, water treatment plants, food processing, cooling water, electroplating, and fertilizer manufacture.

Abandoned mines deposit heavy metals and acid in several streams throughout the State. In addition, nonpoint sources are responsible for a heavy volume of sediment carried by most northern Missouri streams, as well as the Missouri and Lower Mississippi Rivers. Pesticides and herbicides are transported by sediment, causing water quality problems. Proper management of animal wastes through disposal on the land should minimize pollution from this source. Urban runoff is a particular problem in the Springfield area and below Springfield in Wilson Creek and the James River.

Particular water quality problems are as follows:

Grand Neosho River. Turkey and Center Creeks have lead and zinc from mine seepage.

White River. James River is low in dissolved oxygen. Wilson Creek is not meeting standards due to inadequate treatment of municipal and industrial wastes and urban runoff.

Lower Missouri River. Water quality problems result from low dissolved oxygen caused by inadequate treatment of municipal and industrial wastes.

Mississippi River (St. Louis & Cape Girardeau areas & Meramec River). Meramec has high recreation use, but water quality conditions are poor due to inadequate treatment of municipal wastes, industrial wastes, and urban runoff. Lack of aquatic or insect life indicates potentially toxic substances or heavy metals from industrial discharges.

Osage-Gasconade River. Big Piney is area of high quality water and recreational use. Water quality violations are due to inadequate treatment of municipal wastes. Big Creek is low in dissolved oxygen and aesthetic criteria due to inadequate treatment of wastes from unincorporated suburban areas of Kansas City.

Lower Mississippi River. Little St. Francis River does not meet water quality criteria because of toxic substances or heavy metals due to mine waste seepage.

Grand Chariton River. The East Fork Chariton river does not meet pH criteria in water quality standards resulting from acid mine drainage.

MONTANA

The Yellowstone, Milk, and Marias Rivers plus Muddy Creek (Sun River) all experience long periods of high turbidity, particularly from nonpoint sources. Sand Coulee Creek, Dry Fork (Belt Creek), the Upper Stillwater drainage, and the Upper Blackfoot River drainage all have poor overall stream quality due to acid mine drainage. In eastern Montana, coal field developments have heightened the potential for groundwater pollution and sediment pollution due to erosion.

NEBRASKA

Specific water quality problems are caused by inadequately treated municipal and industrial wastes and poorly operated sewage treatment facilities. Natural nonpoint runoff and confined livestock feeding operations result in high sediment loads, bacteria, BOD_5 levels.

Missouri Tributaries

The Papillon Creek watershed within this basin is the most highly polluted area in the State. Fecal coliforms are consistently above water quality standards, and chloride and BOD_5 values are also very high. These high values are caused by poorly treated domestic (municipal) and industrial wastes, feedlot runoff, and poor usage of fertilizers by urban and rural dwellers.

Middle Platte

The Wood River violates water quality standards for phosphates, nitrates, and dissolved oxygen. Some groundwaters in the basin, particularly, along and adjoining the Wood River, have high nitrate values, but chloride concentrations are low in all streams within this basin.

Lower Platte

Salt Creek and its tributary streams contain waters of high specific conductivity and high chloride concentrations. These conditions are due in part to brackish groundwater and surface salt deposits in the drainage area. Sulfate, phosphate, and nitrate levels in Salt Creek are also high and are due to poorly treated municipal and industrial wastes.

South Platte

Extensive irrigation in Nebraska and Colorado is in part responsible for high mineral concentrations in the South Platte waters. Low dissolved oxygen levels from municipal discharges in Lodgepole Creek violate water quality standards. BOD_5, alkalinity, phosphate, and calcium parameters indicate water quality problems.

Big Blue

This basin is characteristically turbid with a mud bottom. Sediment load is usually quite high during periods of even slight runoff. Dissolved oxygen is often low; fecal coliforms often violate State standards; and nitrates show mid to high readings at certain points. Natural runoff, agricultural practices, feedlot runoff, municipal wastes, and industrial wastes all contribute to the present state of Big Blue River.

Elkhorn

Water quality is generally good. Increased turbidity is due largely to nonpoint sources in the runoff area. High fecal coliform levels are due primarily to recent increases in confined feeding operations.

North Platte

Irrigation return flow causes waters to have high conductivity. Turbidity increases after the river enters Nebraska, then decreases prior to flowing into Lake McConaughy. Dissolved oxygen level is high. Many tributaries used for trout propagation indicate high quality of water.

Little Blue

Irrigation return flows represent increasingly large proportion of stream flow during summer months. High turbidity and suspended solids values are present during runoff periods. Low dissolved oxygen levels occur even during low flow periods. Manganese concentration is high in the basin.

Nemaha

Suspended sediment is the prime cause of degradation of water quality due to runoff. Cedar Creek has very high phosphate values.

Republican

Water quality is generally suitable for uses contained in the standards. Chloride concentrations almost triple in the basin resulting from irrigation return flows.

White River/Hat Creek

The White River has naturally high suspended sediment load and mineral content, particularly sulfates.

NEVADA

The most crucial problem the State faces with its surface water is caused by irrigation return flows. Approximately 73 percent of the surface water withdrawn is used for irrigation. The irrigation water which returns to a surface source generally shows an increase in nutrients, temperature, salts, and sediment.

Carson River

The water quality problems in the Carson River are considered severe in some areas, especially as it relates to sustaining aquatic life. The problems are primarily caused by high temperatures and low stream flows.

Leviathan Creek

The creek is contaminated by wastes from an abandoned mine in California, causing severe water quality problems. The area, essentially unpopulated, is used extensively for recreation and fishing, which have of course been adversely affected.

Virgin River

Water quality problems are considered to be severe in the river. The standards for temperature, phosphates, and nitrates are exceeded due to sewage effluents, irrigation return flows, and natural causes.

NEW HAMPSHIRE

The State of New Hampshire is divided into five major basins: Connecticut River, Merrimack River, Piscataqua River and New Hampshire Coastal, Saco River and South Coastal Maine, and Androscoggin River Basin.

Several small towns on the Connecticut River presently dump untreated domestic wastes, but they are not considered critical sources of pollution. The major known sources of pollution are primarily paper mills, the Dartmouth Woolen Company, and a number of municipal dischargers.

The Merrimack River Basin experiences pollution problems as a result of discharges from both municipal and industrial sources. The municipal discharges include Franklin, Concord, Manchester, Tilton-Northfield, Allenstown-Pembroke, and Hudson. The industrial dischargers include a number of tanning, meat packing, and paper mill operations.

In the Androscoggin River Basin serious pollution problems have developed as a result of domestic and industrial discharges from the city of Berlin and the Brown Paper Company. The only other significant source of pollution in the basin is untreated domestic wastes from the town of Gorham.

Only one water quality segment exists in the Piscataqua River and New Hampshire Coastal Basin. Although several municipalities have treatment facilities in operation, upgrading or expansions are necessary in several of the larger communities.

The only serious water quality problems in the New Hampshire portion of the Saco River and South Coastal Maine Basin are in the North Conway and Conway segments of the Saco and the Center Ossipee section of the Ossipee River. These problems generally require upgrading or expansion of old treatment facilities. The only important industrial polluter in the area is the Kearsarge Metallurgical Corporation at Conway Village.

NEW JERSEY

The majority of watersheds are experiencing tremendous pressures from population growth and industrial development, causing the State to classify nearly all surface waters as water-quality-limiting. Of the State's 600,000 acres of shellfish harvesting grounds, one third are condemned. Maximum restoration of the shellfish areas can be achieved only by complete removal of the discharge of treated effluents.

The marine and groundwater problems in New Jersey need further study. Ocean beaches have been experiencing sludge-like materials, garbage, and oil buildups, the sources of which are unknown. The extent and magnitude of the groundwater problem is also not presently known.

NEW MEXICO

This State's pollution problems are primarily the result of a lack of water. This shortage requires massive crop irrigation and tends to magnify the inadequacy of waste treatment facilities.

The intensive irrigation is resulting in high salinity levels in both the surface waters and the aquifer, high sediment loading, and eutrophication of reservoirs from nutrient-rich runoff.

In addition to the nonpoint source problems, overloaded and antiquated waste treatment facilities are discharging inadequately treated wastes into the already overburdened surface waters.

NEW YORK

The major water quality problem in the State is related to the discharge of organic, oxygen-consuming materials, including municipal and the majority of industrial discharges. Sedimentation had a high incidence of noncompliance in several major basins, but primarily in the Genesee and Finger Lakes.

NORTH CAROLINA

Piedmont Section

Most of the developed areas discharge into small tributaries and need tertiary treatment to meet water quality standards. Accelerated eutrophication studies need to be done to determine whether nutrient removal is necessary to protect the water. Finally, the maintenance of acceptable water quality is extremely difficult because of unfavorable dilution ratios, lack of knowledge regarding the degree of treatment required at each source to control the overall problem, operation and maintenance problems with small facilities, and the reliability of existing facilities. Sedimentation is also a major problem in the Piedmont, caused mostly by agricultural practices.

Coastal Plain

The nutrient input from upstream sources, as well as problems with excessive algae growth in the Chowan River, lower sections of Cape Fear, and Roanoke Sound, have placed these bodies of water on the verge of eutrophication. In general, the ecology of the Coastal Plain is quite fragile, and either higher degrees of treatment or control of development appear necessary to preserve water quality.

NORTH DAKOTA

The main problem areas in the State are the James River (Missouri Basin) and the Red River Basin. The James is plagued by an undetermined number of nonpoint sources, and the Red River needs to be studied, especially concerning nonpoint source pollution.

In general, the streams in the western part of the State contain higher total dissolved solids than eastern streams and also contain certain chemicals. However, the eastern part of the State is more highly industrialized and contains the largest population centers, as well as having a high concentration of cattle-feeding operations. For these reasons, a greater percentage of water quality standards are violated in eastern streams.

OHIO

Cuyahoga River Basin

Above Lake Rockwell, the Cuyahoga exhibits water quality problems only during low flows. The causes of these problems are municipal wastewater discharges and nonpoint runoff. The Cuyahoga River below Lake Rockwell exhibits periodic violations of almost every water quality standard established by Ohio. Water quality problems along this portion of the Cuyahoga are caused by waste sludge from Akron, plating plant sludges, thermal discharges, oils, salts, and soil sediments from construction projects.

Maumee River Basin

This basin combines some of the urban problems found on the Cuyahoga with the problems of agricultural point and nonpoint sources, as well as with the problems of towns and industries located on low flow or zero flow streams.

Great Miami River Basin

Downstream sections of the river experience water quality problems associated with complex municipal, urban nonpoint, and industrial wastewater.

Scioto River Basin

Problems emanate from low flows in the headwaters and major municipal discharges on the main stem. The Scioto has the smallest number of industrial discharges of the four basins discussed here, but the Columbus wastewater discharge accounts for approximately 95 percent of the flow of the Scioto River south of Columbus.

OKLAHOMA

Arkansas River Subbasin

The Arkansas River has poor water quality due to naturally high content of dissolved solids. In the Muskegee area, the most common pollutants are heavy metals, cyanide, and nutrients. The basin is rapidly becoming the most highly developed and industrialized in the State.

Lower Verdigris River Subbasin

Water quality is fair to poor due to naturally high dissolved solids content, oil field activity, and municipal and industrial discharges. Dissolved oxygen has been reported near zero, and nutrients are a major problem in Bird Creek, as are heavy metals in Caney River.

Upper Red River and Washita River Basin

Water quality is generally poor as a result of high salt concentrations. There is little rainfall in this region, and tributaries are often dry. The impact of municipal discharges and oil field activities is most frequent at periods of low flow.

North and South Canadian River, Deep Fork River Basin

Heavy metals, cyanide, and nutrients discharged through storm sewers are this subbasin's most frequent problems. Inadequately treated wastes and oil field activities also adversely affect water quality. The North Canadian River doubles in salt content as it travels through Oklahoma City. The area around Ada, which drains to the South Canadian, has problems with brine discharge.

Arkansas River and Salt Fork and Cimmarrod Tributaries

The Arkansas River and Salt Fork Tributaries have poor water quality due to naturally high salt concentrations. Oil field activity also lowers water quality in many tributaries. In the Cimmarrod, water quality is poor due to naturally high dissolved solids content.

Westernmost part of North Canadian and Cimmarrod Rivers

These streams are often dry in summer months. There is an increasing feedlot problem, along with a major siltation problem.

OREGON

For overall management purposes, the State of Oregon has been divided into 20 river basins. Each presents unique management problems as a result of the interrelated influences of population, water uses, water quantities, and general climatic characteristics. Specific basin assessments and water quality management plans are in the process of being developed.

For purposes of this assessment, the State has been divided into fewer geographic areas. These are discussed in general order of priority.

Willamette Basin (Including Sandy Basin)

In 1938 when the State Sanitary Authority (predecessor to the Department of Environmental Quality) was created, the Willamette River was one of the most polluted waterways in the country. Today, as a result of years of effort and the expenditure of millions of dollars for pollution control, the Willamette River has been restored to a level that supports fish life and intensive recreation.

Approximately 1.4 million people, or two-thirds of the State's population, live, work, and play in the Willamette Basin. The waste assimilative capacity of the Willamette River is totally utilized at present. Therefore, maintenance of water quality at present levels will require reductions of present waste loads in order to accommodate future growth and development. The Willamette Basin thus remains as the highest priority area for water quality control purposes.

Within the Willamette Basin, the Tualatin subbasin continues to be a major problem. This area is characterized by rapid residential growth and near zero flows in the subbasin streams during summer months. A master sewerage plan involving elimination of numerous smaller treatment plants and construction of a few large tertiary plants has high priority for implementation.

A few areas remain where localized problems exist as a result of point source discharges. One such example is the South Santiam River where pulp mill wastes continue to cause a summer dissolved oxygen depression and bacterial slime production.

Growth and development in the basin are bringing severe pressures in headwater areas where recreational developments are being proposed. Prevention of pollution in headwater streams is a major element in the overall Willamette Basin water quality control program.

Coastal Basins (North Coast, Mid Coast, South Coast, Rogue, and Umpqua Basins)

Water quality in the coastal basins is generally in compliance or better than standards. Water quality problems can be characterized as being somewhat local in nature and resulting primarily from land runoff, log handling, inadequately controlled point source dischargers, and low stream flows. Principal problem areas include Bear Creek and Rogue River, the South Umpqua River, and Coos and Tillamook Bays. Land runoff, sewage effluents, and log handling activities are the principal sources affecting water quality of Coos Bay. The principal problems in Bear Creek, the Rogue River, and the South Umpqua River result from land runoff, waste discharges, and excessive water withdrawals, which cause low stream flows. Developmental pressures in the coastal areas place a high priority on protection of existing water quality.

Eastern Oregon Basins (Hood River, Deschutes, John Day, Umatilla, Walla Walla, Grand Ronde, Powder, Malheur, and Owyhee Basins)

The water quality in river basins east of the Cascades is generally high; problems arise more from low flow and agricultural activities than is the case in the more populated and industrialized western Oregon basins. Recreational use of waterways is heavy during the hot summer weather and minimal during winter. Principal efforts are directed toward preserving existing high quality waters. In particular, the Deschutes basin is of high priority as a result of the growing demand for recreational developments.

Lower Columbia River (Including Lower Columbia Basin)

Principal problems in the Lower Columbia River are related to temperature, dissolved gas, and coliform bacteria below Portland. Temperature problems are largely natural. Thermal sources such as power plants are being subjected to stringent controls. Potential solutions to the dissolved gas problem are being evaluated by the Corps of Engineers. Completion of secondary treatment for sewage discharged to the Columbia will significantly improve bacterial quality.

South Central Basins (Malheur Lake, Goose and Summer Lakes, and Klamath Basin)

The desert areas of South Central Oregon are generally characterized by a shortage of water. The Malheur Lake and Goose and Summer Lake Basins are relatively sparsely populated; therefore, water quality is minimally influenced by man's activities. The Klamath Basin is highly developed for irrigation agriculture. Irrigation return waters significantly affect water quality. Log handling, which has extensively affected water quality of the Klamath River, is being controlled. In general, the remaining sources of pollution are difficult to control and will require further study.

PENNSYLVANIA

Delaware River Basin

The Delaware River Estuary (head of tide to the State line) has water quality problems from inadequate treatment of wastes from the large population and industrial complex in the Philadelphia metropolitan area. The quality problems are compounded by combined sewer overflows. Programs are underway to improve municipal and industrial waste treatment. The upper portion of the Schuylkill River subbasin experiences significant adverse water quality effects from drainage from abandoned coal mines. The lower portion of the Schuylkill River (Philadelphia and suburban areas) has water quality problems from industrial wastes discharges. The Lehigh River subbasin receives some abandoned coal mine drainage in some of its tributaries, as well as industrial wastes in the lower portion of the subbasin. The Upper Delaware River is generally of excellent quality but is being subjected to development pressure which, if not controlled, could create localized water quality problems.

Ohio River Basin

In the Ohio River subbasin, water quality problems are related to wastes from the heavily populated and industrialized Pittsburgh area. Oil spills in the industrial area create some pollution problems. The Monongahela subbasin has severe water quality problems from abandoned coal mine drainage. Some of the Allegheny River subbasin tributary streams are severely polluted by drainage from abandoned coal mines.

Susquehanna River Basin

The West Branch and the North Branch subbasins of the Susquehanna River have significant water quality problems caused by drainage from abandoned coal mines. There is some localized degradation of water quality in areas where waste discharges are large in comparison to the receiving stream. In addition, in the lower basin there is a nonpoint source pollution problem particularly due to sediments.

Lake Erie Basin

The general quality of the Pennsylvania portion of Lake Erie is good. There are some localized degradation problems near industrial and municipal outfalls, but construction of treatment facilities is underway for the major problem discharges in the basin. Localized problems are caused by combined sewer overflows in the Erie area.

PUERTO RICO

The principal water quality problems on the Island are high coliform counts and heavy sedimentation. Because of this, most of the waters are in violation of water quality standards. There is a difficult abatement problem because of low stream flows. Also, most rivers have tidal problems, with pollutants building up at the mouth of the river.

Marine water pollution is caused mostly by river discharges and direct point source discharges. In numerous places, municipal wastewater by-passes overloaded treatment plants.

RHODE ISLAND

The major areas affected by water pollution are the Blackstone River, Providence River, Lower Pawtuxet River, Upper Narragansett Bay Area, the Mount Hope Bay, and the lower Pawcatuck River. These areas are affected by wastes discharged from out-of-State as well as in-State sources.

SOUTH CAROLINA

Santee Basin

The streams in this basin receive wastes from almost every type of discharge and manifest every potential water quality problem. The Santee is South Carolina's highest priority basin containing a majority of the State's pollution problems.

Pee Dee and Edisto-Combahee Basins

These basins receive wastes primarily from small municipalities and scattered industries. However, nonpoint sources seem to be at the root of low pH and dissolved oxygen levels.

Savannah Basin

The upper one-third of this basin contains several large man-made lakes that receive wastes primarily from small municipalities through tributaries. Generally, water quality problems in these bodies of water are isolated and create no specific problem area. The middle one-third of the Savannah River receives wastes from large municipalities and industries in both South Carolina and Georgia. The lower one-third of the basin is sparsely populated and receives little waste discharge from point sources within the State, but does receive wastes from Georgia.

SOUTH DAKOTA

The primary cause of poor water quality in the State is nonpoint sources, largely the result of poor soil conservation techniques and natural erosion. A general lack of water quality data precludes an in depth assessment of the State's problem.

TENNESSEE

The State has three major water quality problem areas: the Chattanooga area, the Upper Holston Basin, and the Stone River Basin. The poor water quality in these areas is attributed to point sources, both industrial and municipal. Nonpoint sources probably make a significant contribution to water quality problems in many areas of the State, but an assessment cannot be made at this time due to a lack of data.

TEXAS

The State has many water quality problems at present and has the potential for developing more. Since much of the State is semiarid, a high degree of water reuse for irrigation is necessary, which brings with it high levels of salinity, nutrient loading, and sediment loading. In addition, an increased rate of development of industry and second homes, expanding feedlot operations, and poor treatment facilities are resulting in increasing toxic levels, sediment loads, nutrient levels, and coliform and BOD_5 levels.

Most of the potential water quality problems involve the groundwater of the State. Overuse of groundwater, mining activities, injection wells, and artificial recharge are all factors that could result in pollution of the aquifer.

TRUST TERRITORY

No water quality assessment available.

UTAH

Most of the water quality problems in the State are the result of nonpoint sources, which are causing high salinity and sediment loads. The point source pollution problems are localized but severe. At present, the problems are limited to metropolitan areas, but, due to development of subdivisions and recreation areas, the point source contributions are expected to increase in scope and complexity.

VERMONT

Pollution of the waters of Vermont is not severe because of a low density of population and the absence of heavy industrialization. This low concentration of contaminants places the State in a position to attain very high water quality standards; the low concentrations and high objectives, however, create a situation requiring unconventional measures.

The major sources of pollution of the waters of the State are numerous small, widely separated municipalities, a limited number of relatively small industries, and the direct discharge of untreated wastes from individual homes in remote areas.

Of Vermont's population of 440,000, 50 percent is in communities where water quality objectives will be attained through construction of municipal sewerage systems and waste treatment facilities. The remaining 50 percent is in the more rural areas where water quality objectives will be met through the construction of individual home sewage disposal facilities oriented around the septic tank and leaching field concept.

VIRGIN ISLANDS

The water quality problems in the Virgin Islands are almost exclusively due to point sources. The major harbors of the islands are all affected by the discharge of domestic sewage, combined sewers, industrial wastes, and untreated vessel wastes. In addition, the south shore of St. Croix is experiencing pollution problems, including thermal loading violations, caused solely by industries located there.

VIRGINIA

Roanoke River Basin

Water quality problems exist primarily in the urbanized and industrialized areas in the basin: Roanoke-Vinton-Salem, Bedford, Danville, Martinsville-Henry County, and South Boston.

The discharge of treated sewage and surface runoff wastes from the Roanoke-Vinton-Salem urban complex to the Roanoke River area of Smith Mountain Lake causes the outstanding example of water quality degradation in the basin. The Roanoke regional tertiary treatment plant now under construction, and correction of the sewer infiltration problems of the area, will improve the quality of Smith Mountain Lake.

Water quality problems in the Bedford area are confined to tributaries of the Little Otter River.

The Martinsville-Henry County complex of municipal and industrial wastes causes color and dissolved oxygen deficiencies in the Smith River. Upgrading the Martinsville sewage treatment plant, which will serve as a regional facility, to secondary will complete the pollution abatement program in the area. Upgrading of treatment by the City of Danville and surrounding Pittsylvania County, and by industrial establishments in the area, will improve water quality in the Dan River. The Danville regional plant is now under construction.

Secondary treatment for the City of South Boston is also necessary to meet water quality standards in the Dan River. Plans for the improvements are under review by the State Water Control Board, and South Boston has a FY 1974 priority to receive a grant for construction.

Big Sandy and Tennessee River Basin

In the Big Sandy Basin, strip mining has caused erosion and sedimentation problems, and at least one instance of acid drainage, the latter occurring on the North Fork of the Pound River. Correction of these problems will require much effort, manpower, and the cooperation of other State agencies, principally the Division of Mined Land Reclamation of the Department of Conservation and Economic Development.

Sewage pollution problems in the Big Sandy River Basin are typical of those occurring in the mountainous parts of other southwestern Virginia river basins. While the larger communities have installed sewage treatment facilities, many small communities, mostly incorporated, face almost insurmountable financial problems, if they pursue conventional approaches to solution of these problems.

Innovation and fresh approaches will be necessary to overcome the obstacles incidental to preventing the widespread violation of the fecal coliform standards in southwestern Virginia.

Mercury concentrations in fish taken from the North Fork of the Holston River are at levels above those considered safe for human consumption, and the State Department of Health has declared that a health hazard exists. Therefore, the stretch of the River from Saltville to the Tennessee state line is closed for fishing. Mercury in the bottom sediments and biota of the river remain there as a result of the chlorine-caustic plant (now defunct) formerly operated by Olin Corporation at Saltville.

In the Clinch and Powell Rivers, some of the same problems exist as in the Big Sandy River Basin. Sewage treatment facilities have been installed to serve the larger communities, but widespread fecal coliform standard violations result from the many small communities and collections of residences that still discharge raw sewage.

Rappahannock River Basin

The most pronounced water quality problem in the Rappahannock River Basin occurs at Fredericksburg and is the result of wastes from Fredericksburg, its urban area, and the Viscose Division of FNC Corporation. Secondary treatment for the City of Fredericksburg and the equivalent of secondary treatment at FNC have resulted in considerable water quality improvement, but waste loads are still great.

The town of Culpeper causes localized water quality degradation in Mountain Run, and there are other recognized localized water quality effects in streams receiving waters from the other incorporated communities in the Basin; none of the problems is serious.

In the estuary portion of the River, there are minor and localized problems resulting from canning and shellfish process operations and from marinas.

York River Basin

The greatest load of pollutants is discharged from the pulp mill operated by the Chesapeake Corporation at West Point. Dissolved oxygen problems in the York, Pattaponi, and Pamunkey Rivers should be solved when the Corporation's waste treatment facilities are put on line late during the first quarter of 1974.

The American Oil Company at Yorktown has installed and upgraded excellent facilities to treat day-to-day discharges of wastes from its refinery into the York River, and the facilities are protecting the stream from water quality degradation. However, numerous transient discharges of oil from Federal Government and other shore-based installations, as well as from vessels, have caused and will undoubtedly continue to cause problems.

Discharges from many small sewage treatment plants and the installation of many marinas have resulted in condemnation of oyster beds in the lower York River and its tributaries. Some of these condemnations have resulted from high coliform counts, and others are from the buffer zones established by the State Department of Health around sewage outfalls.

On Contrary Creek, a tributary of the North Anna River that flows into Lake Anna, acid drainage occurs from refuse piles remaining on the watershed from abandoned lead, zinc, and sulfur mines. The State Water Control Board is preparing an application for an EPA demonstration grant involving grading and treatment of the area with sewage sludge to alleviate or eliminate the acid drainage.

James River Basin

Many miles of the main stem of the James River, as well as most of its tributaries, are of excellent quality, but severe quality degradation occurs at a number of points on the main stem.

The first point of serious water quality degradation occurs at Covington, on the Jackson River. There, Westvaco Corporation discharges a BOD_5 load on the river that violates dissolved oxygen standards during moderate and low-flow years. Also, the Corporation discharges considerable color and it has a program, approved by the State Water Control Board, aimed at a 50 percent reduction within the next year, and meeting water quality standards within the next few years.

Except for color, which persists, the James River has essentially recovered as far as dissolved oxygen and aquatic organisms are concerned by the time it reaches Big Island. There, the Owens-Illinois Corporation pulp mill discharges a heavy load of industrial wastes that seriously deteriorate river quality, from the standpoint of dissolved oxygen and color.

The river has not yet completely recovered when it receives wastes from a primary sewage treatment plant serving the City of Lynchburg and untreated wastes from the recycled paper mill operated by Mead Corporation. Water quality problems will be corrected when a regional treatment plant providing secondary treatment (final plans approved) is completed by the City, to serve the City, the Mead Corporation, and portions of Amherst, Bedford, and Campbell Counties. Problems from infiltration and discharges from combined sewers in the Lynchburg area require study and development of programs for correction.

The Richmond Metropolitan Area contributes intermittent discharges of storm drainage, raw sewage, combined sewer discharges, and industrial wastes, in addition to a continuous discharge from a secondary treatment plant that has only recently been put on line, serving the City of Richmond and portions of Henrico and Chesterfield counties. The improvement resulting in the James River has not been fully assessed. However, water quality standards violations will continue to occur as a result of the storm and combined sewer discharges during rainstorms. The City of Richmond is proposing to install a holding basin and other facilities to treat storm water overflows from the Shockoe combined sewer, which serves about 50 percent of the combined sewer area in the City.

When Richmond had only primary treatment, dissolved oxygen fell to zero in the James River below Richmond during low-flow years, and the most probable number of fecal coliform organisms rose rapidly. The City's secondary treatment has not been operating long enough to assess what improvement is occurring in river quality. However, the estuary is a large body of water, and dilution and other natural purification factors have operated to permit the river to recover substantially before it receives the large sewage and industrial load from the City of Hopewell and industrial complex.

The City of Hopewell has entered into an agreement with the industries of the area to construct a regional plant by 1976 to resolve any water quality problems that are now occurring.

Small Coastal Basins and Chesapeake Bay

Rapid population and industrial growth have overloaded several of the Hampton Roads Sanitation District treatment plants, causing water quality standards violations in the Hampton Roads area. The problem is further aggravated by massive infiltration and by combined sewers in a small portion of the service area.

Potomac-Shenandoah and New River Basins

In the Shenandoah Valley, there are water quality problems attributable to the poultry industry and the industrial and sewage discharges at population centers such as Waynesboro, Front Royal, Broadway-Timberville, Harrisonburg, Luray, and Winchester. Streams affected are Abrams Creek, North and Middle Rivers, South River, and the North and South Forks of the Shenandoah River.

The City of Harrisonburg and surrounding communities in Rockingham County have established an Authority which is constructing a system of interceptor sewers and a regional treatment facility to serve the entire area.

The major impact on water quality in the Potomac Basin is from sewage discharges originating within the population centers.

The major water quality problem is in the Potomac Estuary below Washington because of inadequately treated effluent from the District of Columbia Blue Plains sewage treatment plant and from the Virginia cities of Arlington and Alexandria and the County of Fairfax. The Metropolitan area of Maryland also contributes to the problem.

Aside from the day-to-day discharges from the aforementioned sewage treatment plants, considerable stream degradation occurs because of urban runoff, combined sewage overflows (principally from Washington, D.C. and the City of Alexandria), and some raw sewage discharges. The City of Alexandria is on a schedule to correct its combined sewer overflows.

New River Basin

Water quality in the New River Basin is excellent except for impacts from the City of Radford and Radford Arsenal. Radford has a primary plant which must be upgraded to secondary to meet water quality standards.

Industrial wastes from Radford Arsenal, particularly nitrates, are causing water quality problems. The Arsenal is on a schedule to install facilities for eliminating these problems.

WASHINGTON

The State of Washington is administratively divided into three regional areas for water pollution control purposes. These areas differ significantly in population density, geographic and hydrologic characteristics, and land use.

Northwest Region

This area contains nearly two-thirds of the State's population and includes Kitsap, King, Snohomish, Skagit, Whatcom, Island, and San Juan Counties. The area is highly developed for urban, metropolitan, and industrial uses. These uses are co-mingled with moderate agricultural and silvicultural activities. The region contains these water-quality-limited segments attributable to point sources: Inner Bellingham Bay, Port Gardner Bay and Inner Everett Harbor, Lake Washington Ship Canal and Lake Union, and Elliott Bay and Duwamish waterway. Control of storm water overflows and bypasses, plus upgrading existing primary municipal discharges to secondary or best practicable technology, will be of primary concern in this area. Design, planning, and construction of other facilities in the Northwest region will be prioritized to applicable effluent limitations and to abate serious health hazards in nonwater-quality-limited areas.

Southwest Region

This area of the State is comprised of the Olympic Peninsula region and the remainder of western Washington south of King County and west of the Cascades. For the most part, this area is comprised of sparsely populated urban and rural areas, except for three areas of dense urban-industrial concentration. Silviculture is a major industry throughout the entire region and is a major source of nonpoint pollution. A second major problem is excessive infiltration-inflow. Two segments (Port Angeles Harbor and inner Grays Harbor) have been identified as water-quality-limited due to point sources. Extensive surveys will indicate the exact sources of excessive pollutant loads, and any waste load allocations required will be made. Priorities again will be based on meeting water quality standards, meeting effluent limitations, and abating health hazards.

Eastern Region

This region consists of all the area east of the Cascade Mountains. Population is sparse in general, and agriculture is predominant throughout. Therefore, pollution problems stemming from agricultural runoff and irrigation return flows are quite excessive. Segments attributable to point sources have been identified as: Mill Creek and tributaries and Spokane River mouth to the Idaho border. Priorities in this area will be based on meeting water quality standards, applicable Section 301 and 302 regulations, and the correction of health hazards.

WEST VIRGINIA

Potomac River Basin

Potomac River Basin water quality is degraded as a result of acid mine drainage entering the North Branch of the Potomac from West Virginia and Maryland.

Ohio River Minor Tributaries

Water quality violations are occurring consistently for lead, chloride, sulfates, phenols, dissolved oxygen, temperature, and total coliform. This is a direct result of discharges of inadequately treated industrial and municipal wastes and of acid mine drainage.

Big Sandy and Guyandat River Basins

In general, there are three major water quality problems within the State of West Virginia. These are acid mine drainage in the Monongahela River Basin, industrial wastes in the Kanawha River Basin, (particularly into the

Charleston area), and coliform densities exceeding limits throughout most of the State, resulting from inadequately or untreated domestic wastes.

The Dry Fork River violates the phenol and total coliform standards. The phenol violation may be the result of associated coal mining activity, and the coliform violations could be the result of inadequately treated domestic wastes or land runoff.

WISCONSIN

The State has two basic problems in connection with its water quality. The first is the upgrading of municipal treatment facilities and imposition of controls on industry. Approximately 50 of the municipalities in the State have only primary treatment of their sewage. Others have overloaded or inadequate secondary treatment. Many industries are violating toxic, temperature, and oil spill standards.

The second statewide problem is the maintenance of high quality waters for fishing and other recreational uses. These waters are a major factor in the State's economy and must be preserved.

WYOMING

For the most part, all waters are meeting water quality standards now. The main problem is maintaining high quality waters and preventing pollution in areas expected to develop rapidly.